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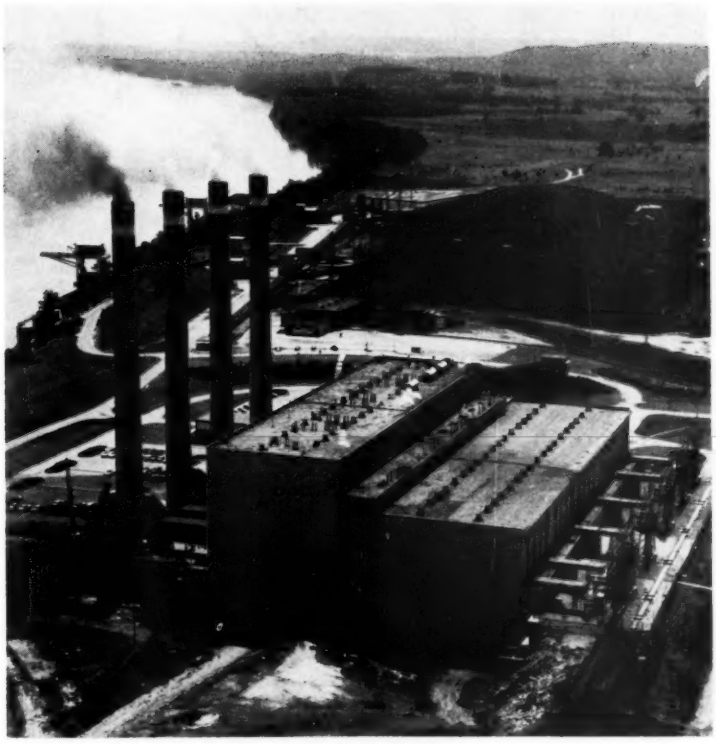
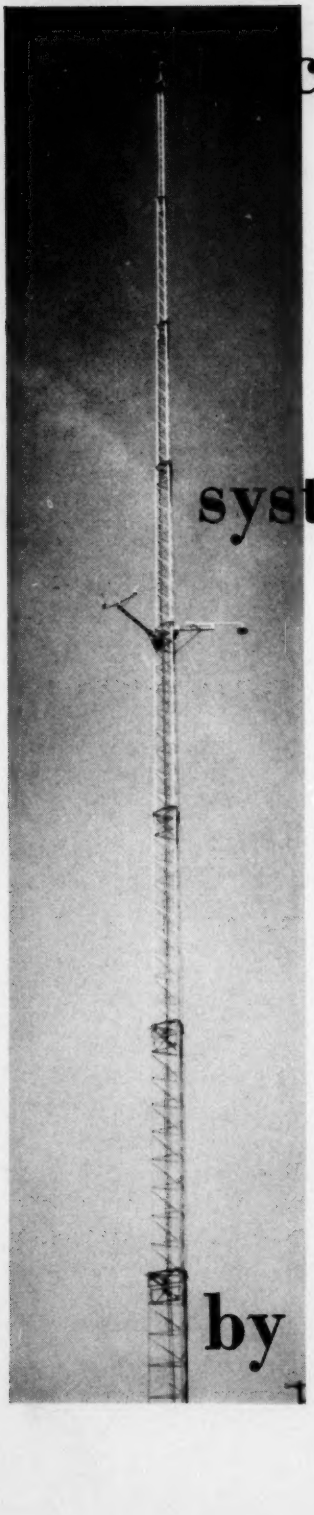


Colbert Power Plant (see page 61)

February 1961
Vol. 11, No. 2
Parts I and II



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JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

A Monthly Journal
Devoted to
Air Purification

Editor: Arnold Arch
Associate Editor: Pat Truschel
Assistant Editor: Pat Martin

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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LETTERS to the EDITOR

International CAW

Dear Editor:

As a matter of interest you may like to know that in the Budget Debate in the Assembly last night I advocated the establishment of a Cleaner Air Week for Melbourne.

I am pleased to advise that the suggestion was well received and I am enclosing one or two newspaper cuttings. The suggestion also had good radio and television coverage and I believe it could be the first step towards bringing this subject to the attention of the community.

Yours faithfully,

JAMES D. MACDONALD
Legislative Assembly
Parliament House
(Member for Burwood)
Melbourne, C.1,
Australia

Of Historical Value

Dear Editor:

Recently I have been working on some of Harry B. Meller's publications, which, I believe, today have considerable historical significance. I believe that a number of these should be reviewed from time to time and some of the more pertinent information used in the JOURNAL, as it would be of considerable interest to all of those interested in air pollution control activities. The following are some of his contributions which I believe are of value.

1 Attached find copy of "Social Significance of Air Pollution" which I think is written in such a manner as to have equal application today. Of particular interest is the subheading "Reasons for Present Conditions."

2 In a paper entitled "Practical Procedures and Limitations in Present-Day Smoke Abatement" written in June 1939, a discussion is given of the significance of the control officer's job as follows:

"The main reason is an incorrect estimate of the kind and size of the job. When an industrial community realizes that keeping the air clean is a project of similar magnitude to keeping streets clean, providing clean water, removing city waste, or guarding the moral atmosphere, then there may be a real hope of success. We usually think of the project in too small terms. It is

(*Continued on p. 89*)

SECRETARY'S PAGE

REFLECTIONS

Anyone who does creative writing is affected by his particular mood at the time he puts his thoughts on paper. This Secretary's page is being written on New Year's Eve and it is a little difficult to project one's thinking into the month of February on such a momentous occasion.

The past year has been an active one for APCA and for your Executive Secretary. Many members have often heard your Secretary say that before we have completed one phase of our headquarters' operation we are planning the next task. And so it goes, hardly have the memories of the eventful annual meeting held in Cincinnati had a chance to grow cold, when the staffing of the committee for the New York Meeting to be held June 11 to 15 began to take place. Even now, the January JOURNAL's final proofs are in the mill and we are planning, not only the February JOURNAL, but the March and April JOURNALS. At press also are the new Governmental Agencies Directory and the New Membership Directory in addition to Proceedings of the last year's meeting.

If these items are not enough to keep your headquarters' staff working at a very high level of output at this time of year, we are busily engaged in a mailing of almost a thousand invitations to membership in response to Dr. Faith's membership campaign letter. Certainly this type of work load does not give us time at headquarters to do much reflective thinking. However, as the days stretch into weeks and the weeks stretch into months in this year of 1960, a pattern has emerged. The membership campaign initiated by Dr. Faith has finally moved off a plateau which was reached at a total membership count of 1800. As of today, the membership figure is 1920. Our publication program is also in high gear and readers will notice that through the fine cooperation of our advertisers we did not have to go to press in January or February completely devoid of advertising. The voluminous mail load at headquarters indicates increased activity and increased interest not only in the field of air pollution control but in APCA as well. In these moments of reflection it is interesting to speculate about APCA's future.

In a recent release of the report of The Surgeon General's Ad Hoc Group on Air Pollution Research Goals entitled "National Goals on Air Pollution Research," estimates are that the increase in expenditures of air pollution research will be increased from the 1960 total of $11 million dollars to a total of approximately $32 million dollars in 1970. Projecting this to APCA's membership and level of activity, it would seem to indicate that APCA should grow in the next 10 years to a total of 6000 members. This is not overly optimistic when it is considered that 10 years ago this month APCA's membership was 300 and the present membership is more than six times that figure. In 1951 there was one local section, today, there are seven. Projecting along the same lines this would indicate over 20 local sections by 1970. Projecting this to APCA's membership and level of activity, beyond a shadow of doubt the local sections hold the association together and are a basic means for recruitment of new members. By the time this report appears in print, it is hoped that the large potential of membership in the Chicago area will be consummated with the petition of MAPPA as a section of APCA.

And now as the old year runs out, this Secretary will put away his crystal ball and get back to work.

Arnold Arch

APPLICATION of Air QUALITY STANDARDS to a COMMUNITY PROBLEM*

BERNARD D. TEBBENS, Sc.D., University of California, Berkeley, Calif., and
DALE H. HUTCHISON, Stanford Research Institute, Palo Alto, Calif.

In developing this presentation, two introductory points will be made, both of which are essentially clarifying qualifications to the use of quality standards for outdoor air. The first is that the ambient air standards in which we are interested are for general community air and do not refer to other situations such as the work place environment. The second is that the application of community air quality standards will have a different economic impact in one location than in another because of differences in geography, meteorology, and sources of a given contaminant.

Amplifying the first point, it is notable that the California Air Quality Standards contain the statement: "The values entered here are determined on a substantially different basis than the industrial exposure standards. These values are, therefore, not appropriate for application in industrial hygiene."[1] The same type of qualification is explicit in the Industrial Hygiene air quality standards, published annually by the American Conference of Governmental Industrial Hygienists. Those most recently available contain the statement: "These limits are intended for use in the field of industrial hygiene and should be employed by persons trained in this field. They are not intended for use, or for modification for use, in evaluation or control of community air pollution or air pollution nuisances."[2]

In recognition of these explicit qualifications, Regulation #2, which affects certain commercial and industrial effluents in the San Francisco Bay Area Air Pollution Control District (BAAPCD), contains a general provision as follows, "This regulation is not intended to apply to the quality requirements for the workroom atmosphere necessary to protect an employee's health from contaminants emitted by his employer; nor is it concerned with the occupational health factors in an employer-employee relationship."[3]

This statement helps define the scope of regulation and allows application of the concepts of the Air Quality Standards of the State of California. Briefly those concepts are that no effects will occur below the prescribed contaminant levels and that the different levels (adverse, serious, and emergency) for any contaminant relate to different but specific physiologic effects. Therefore, air quality better than those levels should be acceptable from the point of view of the health standards of any community or of horticultural, engineering, and maintenance requirements.

As mentioned, the cost of achieving that acceptable quality may be highly variable from one place to another just as is the case with achieving acceptable water. The responsibility of the community then is to determine the value of the air environment to the well-being of its citizens and their property.

Sulfur Dioxide

As a case in point, the California Ambient Air Quality Standards contain complete recognition of the effects of sulfur dioxide on human beings and on vegetation. This is shown below in an excerpt from the Standards:

In accepting these standards for local application, the BAAPCD adopted the same philosophy as the State of California, namely, that present scientific knowledge can only justify controlling the ground concentration of sulfur dioxide. There is of course data presently available indicating that SO_2 enters into reactions with oxides of nitrogen and hydrocarbons with some enthusiasm to form aerosols. However, the data are not sufficient to justify reducing the total emission of SO_2 to the atmosphere at this time.

In further considering the use of these numbers in the BAAPCD Regulation #2, some facts were already known about the SO_2 inventory of the District. From rather limited air monitoring in the District as a whole, and from extensive observation of vegetation damage in the District, it was known that SO_2 concentrations are negligible in most of the area. It was also known that sulfur-containing fuels are limited to liquid fuels, there being so little solid fuel used as to be neglected. Additionally, certain industries which emit sulfur compounds in effluent gases were known as to location, and some were known to have given careful attention for many years to control of emissions in order to avoid ground-level nuisances. Some of those industries had monitored SO_2 at ground level for a long period of time. Some additionally had precise knowledge relating location of emission point, emission rate, and ground level concentrations.

From the known facts, the BAAPCD Advisory Council, found immediately applicable the State Standards for sulfur dioxide. This fortuitous circumstance helped solve a very vexing regulatory problem. In fact, the proposal of a regulatory concept preceded by a few weeks the adoption of the Standards, partly because several persons having to do with the concept were participants in the Standards development. The basis for regulation of SO_2 in the BAAPCD is now control of ground-level SO_2 concentration, fortified by a stack emission limit in those instances where industry does not wish to assume the responsibility of demonstrating that ground concentrations are below the established levels.

Table I

Adverse Level	Serious Level	Emergency Level
1 ppm for 1 hour or 0.3 ppm for 8 hours (plant damage)	5 ppm for 1 hour (bronchoconstriction in human subjects)	10 ppm for 1 hour (severe distress in human subjects)

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

Table II—Maximum Allowable Sulfur Dioxide Ground-Level Limits[a]

Avg. Conc.(c) in ppm (vol)	Total Cumulative Daily Exposure Duration (t) in Hours Between Sunrise and Sunset	Total Cumulative Daily Exposure Duration (t) in Hours Between Sunrise and Next Succeeding Sunrise	Total Cumulative Monthly Exposure Duration (t) in Hours During Hours Between Sunrise and Sunset	Total Cumulative Monthly Exposure Duration (t) in Hours Any Time During Month
Column 1	Column 2	Column 3	Column 4	Column 5
1.51 or over	0.05	0.10	1.00	2.00
1.5	0.62	1.24	4.40	8.80
1.4	0.67	1.34	5.10	10.20
1.3	0.73	1.46	5.90	11.80
1.2	0.80	1.60	6.90	13.80
1.1	0.89	1.78	8.30	16.60
1.0	1.00	2.00	10.0	20.00
0.9	1.14	2.28	12.4	24.80
0.8	1.33	2.66	15.6	31.20
0.7	1.60	3.20	20.4	40.80
0.6	2.00	4.00	27.8	55.60
0.5	2.67	5.34	40.0	80.00
0.4	4.00	8.00	62.5	125.00
0.3	8.00	16.00	111.0	222.00
0.2 or less	No limit	No limit	No limit	No limit

[a] Interpolation of Columns 2, 3, 4, and 5 shall be based on the formulas $t = \frac{0.8}{c - 0.2}$, $t = \frac{1.6}{c - 0.2}$, $t = 10/c2$, and $t = 20/c2$ respectively; where c is the concentration of SO_2 in ppm (vol) and t is the time of SO_2 exposure in hours and c can vary only between a maximum of 1.5 ppm and a minimum of 0.2 ppm.

The pertinent rules of this concept are contained in Appendix A, and Table II.

Especially significant in Table I is the comparison of the BAAPCD limits to State Standards as follows:

State Standards

1. Adverse level
   0.3 ppm for 8 hours
   1.0 ppm for 1 hour

2. Serious level
   5.0 ppm for 1 hour

3. Emergency level
   10.0 ppm for 1 hour

BAAPCD Limits

0.3 ppm for 8 hours
1.0 ppm for 1 hour

1 5 ppm
for 0.05 hour

1.5 ppm
for 0.05 hour

Not only the exact coincidence of the allowable ground-level concentration-time limits at low levels where phytotoxicity is the important criterion but also the relative conservatism of the BAAPCD limits at higher concentration is clear. This conservatism results from the obvious undesirability of ever allowing a ground-level concentration beyond the property-line of a potential offender to be offensive or deleterious to sensitive people of the community. Thus while the basis of both State Standards and BAAPCD limits (Table I) is vegetation damage in the low concentrations, the public interest in the BAAPCD was felt best served by avoiding entirely the possibility of human effects described by the "serious" and "emergency" concentrations of the State Standards.

A significant deviation from State Standards exists in allowing twice as much time of ground-level concentration if all such concentration occurs between sunset and sunrise. This exception, related to vegetation damage exclusively, results from experimental evidence that vegetation is less susceptible to damage by SO_2 during dark hours.[4, 5] However, even then, when the stomata may be partially or totally closed, unlimited time of fumigation at an elevated concentration could produce damage and is therefore not allowed.

While one provision of the regulation appears to limit SO_2 emissions to 2000 ppm by volume, it is notable that more concentrated emissions are allowable if the emitter provides specified surface monitoring and meteorologic services which assure that he is not exceeding the limiting ground-level concentration. This allows the alternative of elevated stack emissions, augmented stack velocities, and other possible meteorologic methods of SO_2 disposal where this procedure is beneficial without creating ground-level nuisance. This appears feasible where a limited number of known major sources is involved as is the case in the BAAPCD and is one reason why the careful inventory of sources is important.

To date this approach to air pollution control has not received the decisive administrative test which must ultimately determine its feasibility. Those who have participated in its development, and there are many, believe it has advantages which outweigh some uncertainties. The concept of controlling ground-level concentration of SO_2 has very strong supporting evidence from the fields of plant and human pathology. That evidence went into development of the State Standards and gives authority to them. Direct and immediate use of that authoritative information has eliminated controversy in establishing a community regulatory procedure which otherwise would encounter all the vexing problems associated with arbitrary numbers.

The advantage to SO_2 emitters has already been stated, namely, the possibility of elevated stack disposal of hot gases without creating nuisance. Clearly the entire concept would be subject to re-evaluation if the Standards were revised in some dramatic fashion.

No other such opportunity has been afforded to an air pollution control district in establishing a control in a large metropolitan community. If mistaken in this impression, we wish to be corrected, but have been unable to discover another instance. In making this statement we are aware of the "alert levels" in Los Angeles, the recommended beryllium level of the A.E.C., the Standards of the Oregon State Sanitary Authority, and the report of the Cincinnati Academy of Medicine. We feel the advantages to be sufficient to encourage similar approaches where applicable in other air pollution control efforts.

Particulates

One instance needs to be pointed out where a similar approach was not possible. This relates to control of particulate emissions in the BAAPCD. Concurrently with the SO_2 standards the California Standards provide a limitation of particulates at the "adverse" level. Specifically this is, "Particulates sufficient to reduce visibility to less than three miles when relative humidity is less than 70%." Without in any way questioning the authoritativeness of this standard, we point out the impossibility of applying it in the BAAPCD in a way analogous to that described for sulfur dioxide.

Some aspects of the problem are comparable to that of SO_2. Particulates from certain commercial and industrial sources are to be regulated by the same Regulation #2 of the BAAPCD. A reasonably good inventory of particulate sources exists.[6] The State Standard was adopted during debate on the regulation and was therefore available. However, it is obvious, as well as documented,[7] that there are particulates

widespread in the environment of the area. Additionally during many hours per year, visibility is reduced below the State Standard limitation.[8]

The very availability of an inventory of particulate sources was one reason indicating that the particulates standard could not be applied effectively in source control. Particulates are emitted from a variety of sources, many of them outside the scope of present regulation. These include home incinerators, automobiles, trucks, agriculture, many industries, and others. Thus the variety and the diffuseness of sources lead only to confusion in attempting to ascribe visibility reduction to some limited groups of them.

At least two additional factors are involved, one being that visibility-limiting particulates are produced from gases in photochemical smog formation,[9] and another that atmospheric agglomeration processes can lead to the growth of visibility-hindering particulates from primary particles too small to affect visibility significantly.

Thus this Air Quality Standard provided no assistance to the BAAPCD in arriving at a regulatory procedure for particulate emissions. Some possibility exists that at a future date development of instrumentation will make the standard useful. The BAAPCD Staff started efforts in this direction almost two years ago, urging development of a measurement device which would correlate visibility reduction in the free atmosphere to light reduction in a plume of particulates.

While this instrumental scheme can conceivably relate obscuration by plumes to visibility reduction, it will not be free of interference from visibility reduction by photochemical smog. In other words, the very ubiquity of light-scattering materials and their precursors may truly make impossible the desired relationship.

Auto Exhaust

As a final consideration of the application of California Standards to a community problem, a word remains concerning the Vehicle Exhaust Standards. The legislative history on vehicle exhaust control was completed in early April 1960.[10] There is probably no member of the Staff, Advisory Council, or Board of Directors of the BAAPCD who does not believe that the application of this standard will have a beneficial effect on the air pollution problem in the Bay Area. Speculation can only center around the magnitude of the benefit, the economic impact, and the ultimate result of what appears to be rather limitless increase in the number of vehicles above the approximately 1.5 million already populating the community.

While reduction of photochemical smog and of carbon monoxide content of the air are anticipated, the vehicular output of primary small particles and of other contaminants would hardly be affected. Thus improvement in visibility might not be all that is anticipated. A large scale test of the premises on which Vehicle Exhaust Standards are based will probably be forthcoming in one or more California communities in the near future.

Conclusion

When ambient air quality standards are based on sound scientific data and are of such character as to eliminate known effects of air pollution on humans or their property, such standards are directly applicable to control of the air environment of a community. Application of authoritative standards removes prejudice and capriciousness from air pollution control, leaving for decision by a community such factual items as the economic value of a satisfactory air quality. A careful inventory of sources of contaminant, of existing contaminant effect in the community, and of meteorology and geography is necessary for estimating the cost and value of such procedure.

Acknowledgment

The authors wish to make clear that this presentation is possible because of the efforts of many individuals who contributed to the development of Regulation #2 of the BAAPCD. These are members not only of the Advisory Council but of the Staff and of the Board of Directors of the District. An additional tribute is paid to the efforts of many individuals who have and will continue to contribute to the Ambient Air Quality Standards of California.

Appendix

3120 SULFUR DIOXIDE

3121 No person shall cause, let, permit, suffer, or allow any emission of sulfur dioxide which results in ground level concentrations of sulfur dioxide at any given point in excess of 1.5 ppm (vol) for 3 consecutive minutes or any of the limits specified in Columns 2, 3, 4, and 5 of Table I. Section 3121 shall not apply to the ground level concentrations occurring on the property from which such emission occurs, provided such property, from the emission point to the point of any such concentration, is controlled by the person responsible for such emission.

3122 Except as provided in Section 3123, no person shall cause, let, permit, suffer, or allow the emission of gas containing sulfur dioxide in excess of 2000 ppm (vol). All sampling of exhaust gases shall follow the techniques prescribed in Chapter 2, Division 8. For purposes of this section 3122, all sulfur present in gaseous compounds containing oxygen shall be deemed to be present as sulfur dioxide, and analyses of samples taken to determine the amount of sulfur dioxide in exhaust gases shall be made as specified in Chapter 1, Division 9. Tests for determining compliance with this section 3122 shall be for not less than 15 consecutive minutes or 90% of the time of actual source operation, whichever is less.

3123 Emissions exceeding the limits established in section 3122 shall not constitute a violation of that section provided that all requirements of this section 3123, to wit, 3123.1 through 3123.9, inclusive, are satisfied.

3123.1 Such emissions shall not result in ground-level concentrations of sulfur dioxide exceeding the limits established by section 3121.

3123.2 The person responsible for such emissions shall have notified the control officer in writing, prior to such emission, of his intent to operate under the provisions of section 3123. Such notice shall include information as to the location of all formation as to the location of all significant emission points, the location of the monitoring stations specified in sections 3123.3 and 3123.4, and the nature of the source operations related to each such emission.

3123.3 Such person shall provide at least three recording sulfur dioxide monitoring stations located in the area surrounding the source, which stations shall be operated in accordance with the specifications of Chapter 4, Division 8.

3123.4 Such person shall provide at least one recording meteorological station equipped to record wind speed and wind direction.

3123.5 Such person shall provide the necessary care and maintenance services so that the instruments will function properly and adequately record sulfur dioxide exposures in the area.

3123.6 Such person shall provide to the control officer a summary of the data obtained from such instruments during each calen-

dar month. Such summary shall be in such form and detail as will show the degree of compliance with section 3121, and the time, location, extent, and duration of any recorded violation of the provisions of section 3121; shall include data giving the total mass rate of emission of sulfur dioxide from the emission points specified in section 3123.2, and a detailed report of instrument performance and maintenance; and shall be submitted within the calendar month immediately succeeding the recording of the data.

3123.7 Such person shall keep for a period of at least one year all records gathered as a result of this section 3123, and shall make these available to the control officer at his request.

3123.8 Such person shall examine at the time of each instrument maintenance check and in any case at intervals of no greater than every seven days instrument records taken pursuant to the requirements of this section 3123 to determine compliance with Columns 2 and 3, Table I, section 3121. At intervals no greater than every forty days, such person shall examine such instrument records to determine compliance with Columns 4 and 5, Table I, section 3121. Any recorded violation of section 3121 shall be reported to the control officer within the next normal working day after such examinations.

3123.9 Whenever the records indicate that a violation of section 3121 has occurred the person responsible for such emission must furnish evidence that proper action has been taken to prevent recurrence, or a violation of section 3123 will be deemed to have occurred and emission will be regulated by section 3122. When instrument records are not adequate to show compliance with section 3121 the control officer may specify the schedule to be followed for producing a satisfactory record history.

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54th ANNUAL MEETING

JUNE 11–15, 1961

HOTEL COMMODORE

NEW YORK, NEW YORK

RECONNOITERING *the* AIR: PROCEDURES *for* ANALYZING *Local Air Pollution* CONCENTRATIONS *and* CONTRIBUTIONS*

J. H. SMITH, Director, Air Control and Research,
Kaiser Steel Corp., Fontana, Calif.

Where should we locate our new plant? What are the long-range prospects of expansion at our present location? These questions and others like them are commonly answered only after careful consideration of market potential, raw material sources, transportation facilities, labor pools, power costs, and the like. But today many industries require consideration of a new criterion—air pollution.

This phrase represents, for many a modern operations executive, a complex of scientific, engineering, agricultural, legal, political, and public relations problems. Among them is that peculiar and often maligned discipline known as meteorology.

The purpose of this paper is not to suggest procedures to be used in a general air pollution survey. Instead, an attempt will be made to indicate techniques that might be utilized in studying how meteorological conditions affect an industrial plant's contribution to local air pollution.

To properly catalogue the factors which will affect the dispersion of atmospheric pollutants in a local area, there must be a proper meteorological reconnaissance of that area. Factors to be studied should include:

1 The local terrain. Define the meteorological boundaries as influenced by structures, valleys, mountains, etc.

2 Local wind trajectories. Classic meteorological techniques will permit projections based on general climatological data such as wind speeds, wind direction, temperatures, relationship to oceans, lakes, mountains, etc.

3 Inversions. Low level air temperature inversions concentrate pollutants, hence their frequency and duration are important factors to be considered.

4 Location of plant. It is essential to know where a source is located with respect to other plants, population concentrations, and agricultural development — the tolerance of the subject defines the toxicity of the agent.

There may be additional factors which will come to mind as one proceeds to map out a plan for meteorological reconnaissance. But any study to determine the precise effect of these gross factors on local meteorology will profit from maximum use of the following aids:

Determining what is in the air and, to a degree, where it comes from can be achieved by taking samples of both the ambient air and contributing gases at the source of emission, e.g., directly from the plant stacks. Methods and equipment are readily available for determining the nature and concentrations of most known pollutants. Again, it is not the purpose of this paper to list the specific techniques for determining nature and concentrations. These may be found in the literature or by contacting the local air pollution control official. A word of caution—one should be careful to select techniques permitting the desired type of separation. In some instances modifications are required if one wishes to separate gaseous from particulate concentrations of the same pollutant.

The question of where the material is transported within local meteorological parameters may be answered a number of ways. The easiest way, of course, is by visual observation. One merely watches the plume and notes the direction of its path. The type of plume as noted by P. Church[1] may be determined and compared with classical forms of plumes which have been related to differing meteorological conditions. However, a more refined technique is to apply the various mathematical equations such as Sutton,[2] Deacon,[1] and Bosanquet and Pearson,[1] to determine degree and speed of dispersion. The use of wind speed traces as developed by Brookhaven[3] personnel further refines even this technique. Naturally, if the air is clear, no movement can be detected; however, it is possible to establish local flow patterns by artificial plumes from smoke sources temporarily mounted at the source to be studied. In this manner not only can the mean air movement be observed but also the stability. This latter value enters into most diffusion problems in one way or another.

Time Lapse Photography

One aid offering a great deal of possibility in air transport studies is the use of time-lapse moving pictures. If the plant in question has a visible effluent, much can be learned by time-lapse photography in conjunction with certain meteorological procedures. This technique approaches quantitative values, and may provide one with more useful data than a combination of other methods. The application of this technique depends, of course, on the ability of the viewer to discern the plant effluent when the film is projected. Time-lapse photography permits a "compression" of time, in that the film is projected at the normal rate of 16 frames/second while the pictures may have been taken at a rate of one every 13 seconds—a compression of 13 x 16 or 208 times faster than normal. Thus, a 10-hour day of time-lapse photographs can be projected in three minutes. In the hands of a competent meteorologist, the time-lapse film may reveal not only the path and extent of the plume but may also indicate inversion levels, shear lines, deviations

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* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

from calculated wind trajectories, and the like.

The technique is relatively new and, as a consequence, the equipment available is in need of refinement. However, one organization[4] has developed an intervalometer which will permit film speeds ranging from 1 to 110 seconds/frame. This particular device will also permit operation on a 12-volt battery system. The unit requires very little current thus avoiding frequent attention to battery replacement. The entire system includes a 16 mm, electric eye, magazine lead camera attached to a small rewind motor. The rewind motor is controlled by an electric timer. The entire mechanism may be controlled by utilizing a photoelectric cell which can be so adjusted that it will turn the system on as soon as there is sufficient sunlight to register on the color film and then turn it off when the light intensity falls below the same value in the evening.

The time-lapse unit must be placed at a point where there is an adequate view of the area to be surveyed. Usually this will require a hilltop or a tall building. It is most helpful to have a good backdrop such as hills or mountains to provide a contrast with the effluent being photographed. However, the sky will normally suffice.

The meteorologist can be assisted further by oblique aerial photographs of the area in color or black and white, taken at different hours of the day. Aerial photographs may indicate diffusion patterns of the effluent. Very often the aerial photographs will reveal anomalies from the calculated wind trajectories. In all studies where large areas are under investigation and where aerosol movements are being tracked with ground based time-lapse cameras, it is informative to have "check points" of the aerosol distribution. That is, if one can obtain overall pictures of the distribution at specific times, the subsequent analysis of the time-lapse films becomes more meaningful since the distances of masses of pollutants from the camera sites can be measured directly. With this in mind, aerial "surveys" may be made twice a day at two different altitudes. These will furnish the desired information in the form of a plan view distribution over the area under surveillance. Aerial photographs have clearly demonstrated mass movement of smog banks during the course of a day.

Transport of the effluent can be plotted more accurately if one includes an anemometer and clock in the field of the movie camera thus providing an additional quantitative measurement to the meteorologist. Before leaving the subject of time-lapse photography, it might be pointed out that the technique can be used to monitor the plant control equipment. Many air pollution control laws or regulations prohibit the emission of smoke exceeding various shades of the Ringelmann Chart[5]. By setting the frame speed at one frame per minute, one can merely scan the footage to determine where corrective measures are necessary.

Another unique and useful tool for following airborne pollutants is the silver iodide tracer technique. Some meteorologists[4] have used this device to considerable extent, and it has proved quite satisfying in actual field studies. Two features of the silver iodide technique make it most attractive: First, the properties of silver iodide smoke are usually different from other industrial effluent, and secondly, it may be dispersed in a hot medium thereby approximating the temperature of combustion products from most pollution sources.

AgI Easily Isolated

Silver iodide (AgI) is not only unique as an aerosol compared to most other elements in the atmosphere but, by virtue of its special properties as a freezing nucleus, can be easily isolated from most other air pollutants. Basic research by B. Vonnegut[6] uncovered the fact that the AgI crystal was almost identical to that of an ice crystal and when introduced into a supercooled cloud of water droplets, formed an ice crystal due to the deposition of water on the AgI crystal. This phenomenon, a commercial aspect of which is cloud seeding, can be put to work in effluent tracing through the use of portable "cold box" samplers. "Cold boxes" are simply refrigerated boxes capable of cooling an air chamber to at least $-20°C$. When water is introduced into the chamber as an atomized water mist, it will remain in the liquid state until freezing nuclei enter the chamber through an intake tube. The instant such nuclei are present, the droplets deposit upon them and form ice crystals. The determination of the number of nuclei is a visual one wherein the number of ice crystals formed per unit volume per unit time are actually counted by means of a calibrated optical system. Although the use of manned samplers may seem restrictive, they provide the mobility so often necessary to track down a plume. In fact, by using three units mounted on trucks, it may be feasible to plot the values of concentration both parallel and normal to the plume axis. An automatic system of a dense network might provide the same results yet one is never certain that a fixed position of a unit is in the optimum position. With mobile units one can at least find the main axis and proceed to make sequential checks in the vicinity until some semblance of pattern is determined. After the AgI is dissolved in an acetone solution it is then burned in a propane flame at about 1250°C. The flame is contained in a metal cylinder whose axis parallels the flame axis. One function of the cylinder is to cool the smoke sufficiently to produce AgI crystals. Cooling in this sense is relative in that the "smoke" is still several hundred degrees.

There does exist some controversy over whether or not the sun's effect on the AgI crystal is sufficient to destroy its effectiveness as a freezing nucleus. The latest information shows that with humidities greater than 50% the photolytic decay is negligible. The need for a night-time investigation of air movement may arise. The AgI technique applies very well to night-time dispersion studies.

There are other materials which can be used as tracer compounds. Studies have been made using zinc-cadmium-sulfide, antimony oxide, cobalt, etc., with reported success. It is believed that the silver iodide technique overcomes most of the objections stated about some of the other materials.

Without smoke plumes or aerosols it is practically impossible to determine vertical stability unless one conducts some type of sounding operation. Tethered balloons can be used to carry an aerometeorograph up to 5000 ft. This will provide the necessary vertical gradient to calculate stability. The aerometeorograph records temperature, pressure, and relative humidity of the air as it passes from one level to another in its flight.

The determination of upper wind movement may be found by the use of pilot-balloon measurements. The balloon, when properly inflated with hydrogen or helium, will rise at a relatively uniform rate and will drift freely with the winds. The balloon's position is recorded periodically, from the point of origin, by use of a theodolite. The speed and direction of the wind at each level can be derived from the recorded values.

Determining Air Pollutants

Determining concentrations of air pollutants at varying distances around the compass may appear to be a difficult task. However, by using the estimates obtained from the mathematical techniques and the data from the tracer studies, one should be able to forecast concentrations fairly well. The values should then be correlated with those obtained by actually checking the vegetation in the area. A competent plant pathologist or ecologist experienced in recognizing air pollution

symptoms may assist in defining areas of pollution. Symptoms of air pollution plant disease are now fairly well understood and will often reflect the nature of the effluent as well as approximate concentration and source location. It is a good idea to photograph, in color, the expressions found on vegetation in the immediate area.

The area should be laid out on a grid basis and specific sampling points selected, based on a statistical evaluation of the meteorological data. The pathologist can then accumulate case histories at each sampling station for evaluation. By noting the syndrome, the pathologist can offer valuable assistance with respect to the area of greatest fumigation and the nature of the fumigant. In some instances he may be able to estimate the concentration of fumigation. Certain types of vegetation serve as excellent "indicators" to the experienced pathologist. The chemical analysis of the vegetation at each sampling station will permit a quantitative measure of the nature and concentration of certain known pollutants.

By going a step further and obtaining yield and production records of agricultural crops in the area, one can assess the seasonal and climatological variations utilizing standard statistical techniques. Further, variations due to cultural practices can be isolated and thus removed from the air pollution picture.

All of the aforementioned aids may be supplemented by the rapidly improved measuring techniques and devices now on the market. There have been refinements made in some of the older measuring techniques such as dust fall measurement, determination of soiling effects, corrosive characteristics, etc. These are more or less general in their application. For more specific applications there are instruments now available to automatically sample and record such pollutants as SO_2, ozone, oxides of nitrogen, CO, fluorides, etc.

The meteorologist and the air pollution scientist who is acquainted with, and who makes use of, these techniques has much to offer industry, agriculture, and the community toward a better understanding of air pollution problems. The long range benefit of such studies will, in most cases, far outweigh their cost.

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An Interim REPORT on FULL-SCALE STUDY of DISPERSION of STACK GASES*

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When O. G. Sutton[1] and Bosanquet[2] presented their now well-known and widely used equations for mathematical analysis of dispersion of gaseous emissions, only limited field data were available for testing their application to industrial air pollution sources. In recent years a number of investigators have taken extensive measurements of ground level concentrations, and from these and associated meteorological data they have derived estimates of appropriate diffusion parameters for the Sutton and Bosanquet equations. More limited measurements have been taken above ground level from towers and samplers suspended from balloons.[3–5] These studies have generally been restricted to relatively small simulated or industrial sources where pollution measurements were taken from 50 yards to one or two miles from the source. While investigations to date have facilitated the application of diffusion equations or theories to several types of industrial sources, three-dimensional measurement of dispersion of major sources out to relatively great distances has not been reported.

This discussion is an interim review of a full-scale study of dispersion of stack gases from large coal-burning power plants which was initiated in July 1957. When the Tennessee Valley Authority initiated construction of the first of a number of large coal-burning power plants in 1951, due attention was given to air pollution concontrol. The constituent of flue gas emissions of special interest was sulfur dioxide. Extensive use was made of automatic stationary recording SO_2 samplers, Thomas autometers, to monitor ground concentrations. Complete meteorological stations and operational information provided basic data for applying the classic diffusion equations in estimating both levels and frequency of concentrations at selected locations. Initially, agreement between measured and calculated levels was poor. Some improvement was achieved by more accurate determinations of effective stack height and allowance for "swing of the wind" during the sample period. Even so, early in TVA experience it became obvious that commonly used diffusion equations were generally unreliable for estimating dispersion of power plant stack gases.

To supplement data which accumulate relatively slowly at stationary autometers, a portable model Titrilog was acquired and adapted for mobile operation in an automobile.[6] The Titrilog operated in an automobile was a valuable adjunct to stationary monitoring instruments. However, numerous areas of interest were inaccessible by road. Also, we felt that measurement of dispersion in the entire plume was desirable for understanding and interpreting data taken at ground level. Accordingly, the Titrilog was adapted for operation in Bell Model 47-D-1 helicopters which are used for power line patrol and mosquito control operations in TVA.[6] Initial operation of this equipment at the plant has been described by Gartrell and Carpenter.[7] In this early work, the pilot followed a prescribed flight course, usually downwind or upwind in the center of the plume. While the data contributed toward an explanation of dispersion processes, particularly inversion breakup, they did not provide an effective measure of dispersion in the complete plume.

To overcome this deficiency auxiliary instrumentation was added and the equipment was mounted so that an engineer-observer might accompany the pilot and direct the same flights. The sample plan was revised to include cross sectioning at plume quarter points at selected intervals of distance from the plant. In this manner, the inversion plume could be defined with reasonable accuracy for considerable distances. Data included the geometry of the plume at selected cross sections and a record of SO_2 concentration at quarter sections. The potential usefulness of this technique for atmospheric diffusion studies led to the current full-scale diffusion study of power plant stack gases. The study is being conducted co-operatively with the U. S. Public Health Service as a part of the federal air pollution research program.

The Colbert Steam Plant (Fig. 1) was selected for the principal part of the study. The Colbert plant is located 12 mi southwest of Wilson Dam, Alabama, in an area of relatively flat topography. Of the several TVA steam plants, it was favored for study because of the weather regime which includes a wide range in wind velocities and both strong lapse and strong inversion conditions. Design and operational data of interest in air pollution studies are found in Table I.

So that dispersion from the four 300-ft Colbert stacks might be compared with dispersion from higher stacks more nearly approximating a point source, some sampling was planned at one of the other plants during a period when two 250-mw units were to be operating on a single 500-ft stack.

One to two months of actual field sampling in each of three years was considered the minimum to adequately define dispersion. Principal meteorological models proposed for study included (1) inversion, (2) coning plume in high-wind conditions, and (3) looping plume in low to moderate wind conditions if considered feasible after analysis of the first two models. Study of inversion-type plumes was scheduled first. Phases of the study include (1) field sampling and observations, (2) reduction and consolidation of field charts and related meteorological and air pollution data, (3) data analysis and formulation, and (4) summary of results and final reporting. While a limited amount of additional field

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Fig. 1. Colbert Power Plant, site of dispersion studies.

sampling may be necessary, we are now essentially in the third phase of this project, i.e., data analysis and formulation.

Basic Instrumentation

Helicopter

In this dispersion study a number of modifications were made in the original installation reported by Gartrell and Carpenter, and some auxiliary equipment was added. Equipment used in the helicopter includes (1) the portable model Titrilog and recorder on a cushioned mount between the pilot and flight director, (2) an open-face thermister thermometer and probe for air temperature measurements, (3) a spring wound clock readable to the nearest 0.1 minute, (4) an air speed indicator, (5) an altimeter for identifying and maintaining desired flight elevations, (6) a sample intake probe extending about 12 in. ahead of the cockpit canopy, and (7) a dictaphone for recording temperature, elevation, and other pertinent observations. To minimize power requirement the manifold vacuum of the helicopter engine is utilized to pull the sample through the Titrilog. Constant sample rate, about 1000 cc/min, is maintained by means of a vacuum relief valve in the line between the sample intake and reaction cell.

Arrangement of this equipment in the helicopter is shown in Fig. 2. Because of excessive friction loss it was not practical to sample at an isokinetic velocity, 44 fps corresponding to the constant air speed of 30 mph. Actually a sample rate of about 20 fps was maintained. However, laboratory tests with simulated flight conditions established that in all plume cross sections requiring more than 20 sec to traverse, approximately 95% of the actual maximum SO_2 concentration is recorded. The open-ended, flow-through sample line from which the Titrilog sample is drawn, Fig. 3, is required for obtaining a representative sample. Considerably greater departure from true plume concentration was experienced with a single sample line extending directly from the intake point to the reaction cell.

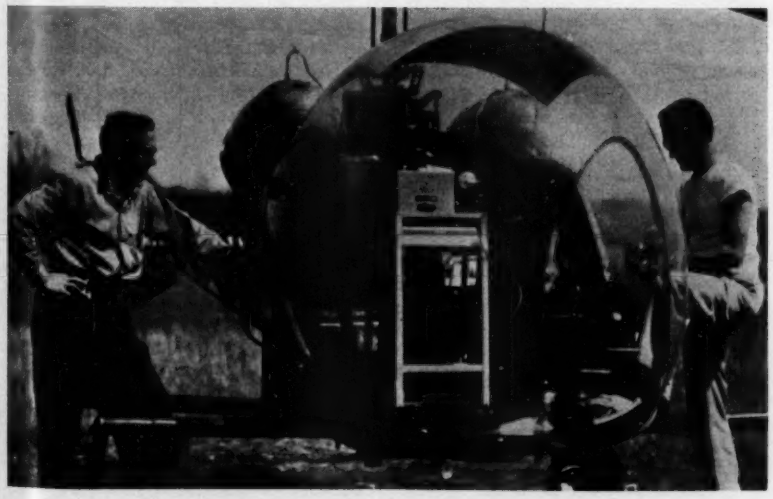

Fig. 2. Arrangement of equipment in helicopter used for dispersion studies.

Table I—Design and Operational Data, Colbert Steam Plant

Total rated capacity, kw	720,000
Number of units	4
Unit rated capacity, kw	180,000
Unit capability, kw	200,000
Total capability, kw	800,000
Number of stacks	4
Spacing of stacks, ft approx	100
Height of stack, ft	300
Diameter of stack, ft	16.5
Exit velocity of flue gas, fps	47
Temperature of flue gas, °F	290
Coal consumption per unit day, tons	1,800
Average sulfur content of coal, percent	1–3.5

Meteorological

A standard meteorological station common to all major TVA steam plants was located 0.78 mile SE of the Colbert Steam Plant. This site served as the base for field studies. A nearby open area was used as a heliport and an office trailer was stationed nearby for storage of equipment and labeling, identification, and limited field appraisal of records. Wind and temperature data were taken from a 221-ft steel tower equipped with aerovanes and temperature probes. Continuous records of wind speed and direction, surface temperature, temperature differential between the surface and top of the tower, and wet bulb depression were available. The tower was augmented by a cotton states shelter with hygrothermograph and maximum and minimum thermometers. In early studies, a portable recording ground wind system was operated to provide data on surface wind direction and velocity. This was later replaced by a hand-held anemometer. A theodolite was also set up at a nearby release point for observation of pilot balloons.

Steam Plant

All routine operational data kept at the steam plant were available. Data of some use in dispersion studies included barometer readings, number and level of unit operation, Orsat flue gas analysis, temperature of flue gas, coal-burning rate, and coal analysis, particularly sulfur content. To provide more precise data for correlation with dispersion data, the average SO_2 concentration in flue gas was obtained by iodometric absorption during the period of all sample flights. Samples were taken from the duct between the in-

duced draft fans and the stack. Sample flow was accomplished by inserting scrubbers in a line extending from the pressure side of the induced draft fan to the fly ash collector outlet where a vacuum equivalent to about 18 in. of water exists. The average SO_2 concentration was obtained for successive 30-min periods. Concurrent with SO_2 samples on one of the four units, representative coal samples were taken from the several scales serving the unit. The relation established between SO_2 concentration and sulfur content of coal was applied to all units in deriving estimates of SO_2 emission rate from the entire plant. Actually, the two measurements of sulfur were not in great disagreement. As a general rule sample data indicated that about 90% of the sulfur in coal passed up the stack as SO_2 (this includes 1 to 2% as SO_3). Coal and flue gas sampling was carried out by personnel of the power plant.

Aerial Sampling Plan

Several tests and considerable study were devoted to development of an effective sample plan. The objective was a procedure which would provide adequate definition of SO_2 distribution in a plume cross section while allowing time for sampling of several sections as well as for other supporting work. Meteorologists assigned to the study by the Public Health Service who accepted responsibility for operation of meteorological equipment also were particularly helpful in developing sampling plans. The sample plan employed in most of the field work to date is illustrated in Fig. 4. Replicate flights were made across the plume center line, the top and lower quarter points, and the elevation of the top and bottom of plume determined at selected distances from the plant—usually 1/2, 3/4, 1, 2, and 5 to 10 miles. Elevations of the 1/4 points and of the center were largely dependent on judgment and observation. Where wind shear or other factors develop skewness, the room for error is evident. Subsequent plotting of data revealed such skewness in some instances. Therefore, the sample plan was modified to eliminate this possible error in judgment. In the present plan the elevation of the plume top or crown is estimated by observation and then checked by the flights at different elevations to find the elevation at which only an occasional trace or minor registration of SO_2 is visible on the chart record. Replicate flights across the plume are then made at successively lower levels until no registration occurs. The vertical intervals for a particular cross section are constant and vary from 50 to 200 ft, depending on the over-all depth or thickness of the plume.

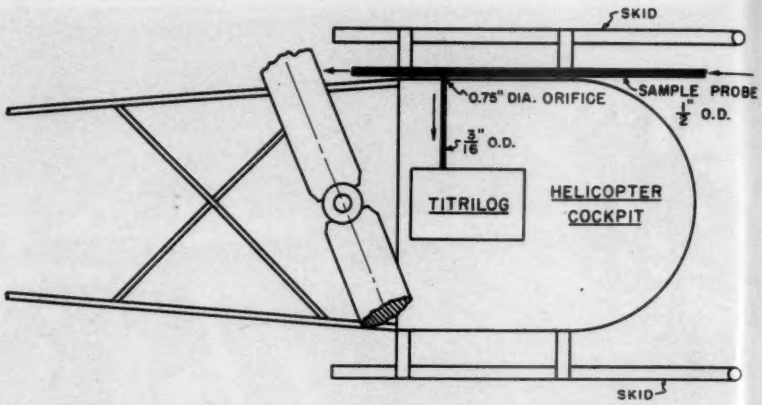

Fig. 3. Open-end, flow-through sample line used for Titrilog sampling in helicopter.

The distribution of SO_2 in a plume has been a subject of some question. Diffusion equations are based on the assumption that a normal distribution exists. Our experience in an inversion plume supports this assumption. For example, the SO_2 distribution as reflected from reproduced charts is shown in Fig. 5. A second item of special interest in this figure is the close agreement between replicate flights at the same elevation.

Vertical Temperature Data

Initially, plume cross sections were supplemented by flights along the top, center, and bottom of the plume to establish air temperature at these elevations. Subsequently, four landmarks prescribing a square of about 1 mile were selected in the vicinity of the meteorological station as a basic reference for all temperature data except that taken inside the plume. The need for some information on air temperature above the plume was recognized. Therefore, a plan was adopted where the copter ascends 500 ft higher than the top of the plume and then descends in a slow, smooth spiral following the established landmarks. Temperature and elevation readings are taken on passing each landmark, resulting in a value for air temperature for about each 100-ft vertical interval. As a check and for correlation with ground based systems, temperatures are also read in horizontal flights at the top and bottom of the meteorological tower.

Procedure for a Typical Sample Day

The mechanics of the field phase of this study are perhaps best illustrated by summarizing the sequence of operations for a typical day. Initially, field operations are normally scheduled in that season of the year when the frequency of desired weather conditions is highest; i.e., inversion plumes in

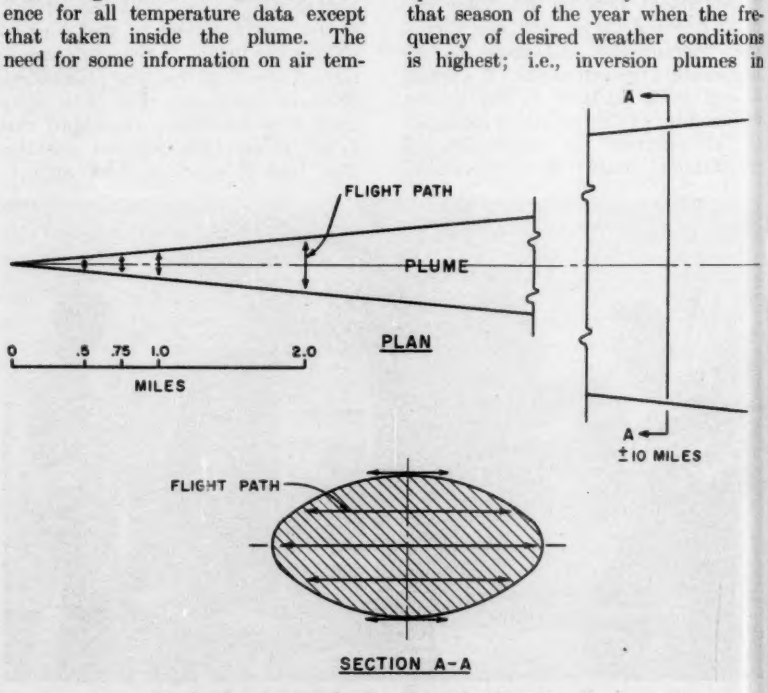

Fig. 4. Sampling plan for dispersion study of inversion plume.

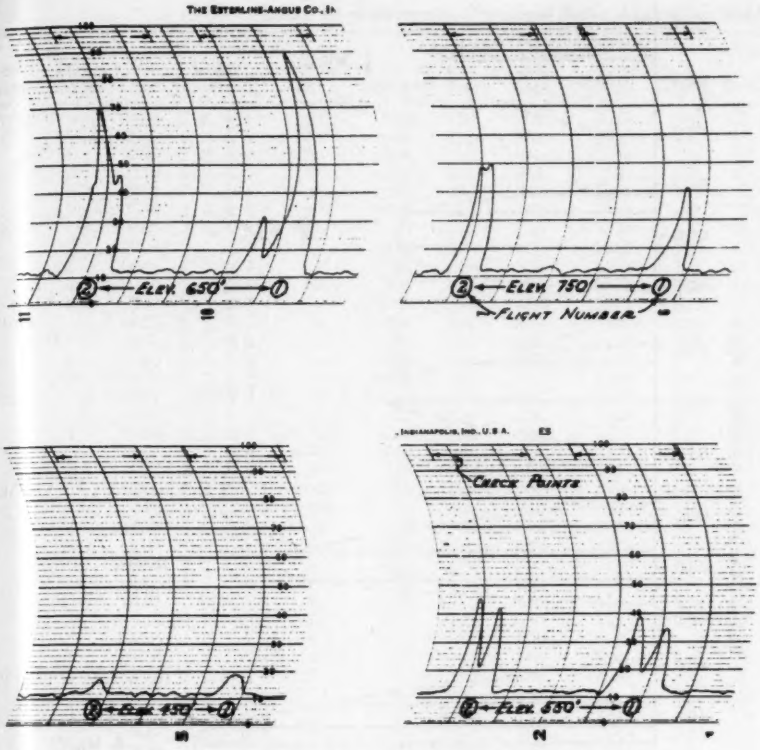

Fig. 5. Titrilog charts showing distribution of SO_2 in sections of an inversion plume.

September-October and streamline or coning plume with high velocity wind in March-April. In this instance sampling in an inversion plume is described.

Each evening at about 6:30 PM, before a day of anticipated sampling, an advisory is provided by the office of the U. S. Weather Bureau, Knoxville, Tenn. This advisory describes the probability of an inversion the following morning as well as its estimated elevation and intensity, wind speed and direction, and other related information. If the outlook is favorable or moderately so, personnel are alerted to arrive at the field headquarters about 30 min to one hour before daylight. En route to the field base, the Titrilog is operated in a car for warming up and checking for malfunction which might require emergency repair or use of an alternate machine.

Beginning at or sometime before daybreak, meteorological data from the above instruments are logged each 30 min and pibal observations are taken. A small light attached to the balloon permits nighttime observations. Observations are made on balloons until they are obscured by high cloud cover or lost. To conserve manpower and permit more frequent observations, theodolite readings are dictated into a recorder. At daybreak the Titrilog is transferred from car to helicopter, and it and other instruments are checked out. Following takeoff, horizontal flights are made to check temperatures at the bottom and top of the meteorological tower; the vertical temperature is determined by prescribed flight pattern at 100-ft intervals starting at above 500 ft above the top of the plume. By means of an intercom system, plant personnel are alerted to begin special coal and SO_2 sampling at the approximate time that actual plume sampling is begun.

Normally, cross sections are begun at $^1/_4$ mile and continue at progressively greater distances as time permits before strong changes in the thermal and wind structure occur. Actual plume sampling time usually averages about two hours in which time cross sections are taken at about four points downwind from the plant. In flight, the observer records temperature and elevation data, marks the Titrilog chart for later identification of each plume transect, and enters other pertinent observations on the chart or voice recorder.

Upon completing plume transects, temperature soundings are repeated before the flight is terminated. Coal and SO_2 sampling are discontinued at this time. Based on observations, experience, and to some extent temperature changes at the meteorological tower, a flight is made to sample SO_2 concentration near ground level occasioned by inversion breakup. This might be described as a treetop flight in line with and along the plume center line as based on observation and judgment. It usually consists of a downwind and upwind return flight. In open land an elevation of 50 ft above ground is maintained, while in forested areas the elevation is about 100 ft.

In a part of the flights when personnel was available, time lapse color photographs were taken of the plume. In this activity a Bell and Howell movie camera equipped to control time interval exposure was used. The camera was mounted on a plane table approximately normal to the plume at distances which would include one to three miles of plume. By means of vernier for measurement of vertical angle, the location and elevation of the camera, and direction of plume travel, it should be possible to resolve vertical plume dimensions at various distances from the plant.

Upon completion of flights, all charts are reviewed and permanently labeled for later study. A part of the voice recordings, particularly such numerical information as theodolite and temperature readings, is transferred to appropriate data sheets.

Compilation and Analysis of Data

The geometry of respective plume sections may be developed and plotted from Titrilog charts and elevation data. Width of individual transects is determined by length of chart which records a trace or more SO_2 and the true speed of the helicopter. In Fig. 6, cross sections as developed from such data are shown at $^1/_2$, $^3/_4$, 1, 2, and 6, and 9.5 miles distance from the plant. It may be noted that in the $2^1/_2$-hour period of sampling no vertical diffusion of the plume is evident. However, in this period the width of the plume increases from 1600 ft at $^1/_2$ mile to 4000 ft at 9.5 miles.

From plots of this type and other data sources previously described, the following information is compiled for each plume section sampled.

1. Average and peak SO_2 concentrations in section
2. Plume width and depth
3. Approximate cross sectional area
4. Approximate elevation of plume center line
5. Average wind speed in plume
6. Lapse rate °F/1000 ft from ground to center line of plume
7. Standard deviation along the y and z axes
8. SO_2 (Flux) in section, expressed in arbitrary units in a one-foot plume segment
9. Plume direction in relation to line of stacks

In September-October 1957, a total of eight successful sample runs was made at the Colbert Steam Plant during inversion conditions. Basic data from these flights are summarized in Table II.

With these data at hand the diffusion

parameters appropriate for application in the Sutton diffusion equations may be readily calculated. The dimensionless parameter "n" may be calculated from the wind profile data or plume geometry and concentration data. The latter data have been used to compute values of n using: (1) the relation of the standard deviation of concentration along the y axis with distance from the source, (2) the relation of the average or maximum center line SO_2 concentration with distance from the source, (3) the relation of plume width to distance from the source, and (4) the relation of the average concentration and wind speed with distance from the source. We have found reasonable agreement in values of n computed by the different methods utilizing plume geometry and concentration data. However, these values of n in every case were higher than values computed from wind profile data. With any accepted value of n the diffusion coefficients Cy and Cz may be computed directly from the relation of plume width and depth to distance.

In March-April 1958, nine flights were made at Colbert to define dispersion in high-wind conditions. In March-April 1959, four high-wind flights and one inversion flight were made at Colbert. Data from these flights have been compiled but have not been analyzed.

Apparent Loss of Sulfur Dioxide in the Plume

As one step in the analysis of the eight inversion flights made in 1957, the maximum SO_2 flux was estimated at each plume cross section. This is expressed in terms of units per lineal foot of plume, Table III.

While there are exceptions, there is evidence on a number of days that SO_2 flux as calculated from the Titrilog records decreases with distance and time from the source. This is particularly apparent at distances greater than two miles. Oxidation of SO_2 to compounds which are not recorded by the Titrilog was considered as a possible explanation. The reverse trend on October 8, 1957, occurred on the single day when sampling progressed from the most distant point toward the plant. A possible explanation of this exception might be the effect of increasing sunlight on the oxidation process. These hypotheses are in the nature of conjecture since it is recognized that the values of SO_2 flux are highly dependent on wind velocity data which may have limited accuracy in this area. However, analysis of the field data by two independent groups outside TVA provided estimates of similar magnitude and variation.

Investigation of Oxidation of SO_2

Since the above-mentioned data suggest a possible oxidation of 20 to 40% of emitted SO_2 in a distance of 10 miles and a time of one to two hours, further investigation was considered necessary. It was considered that this process might exert a significant effect on diffusion parameters derived from SO_2 measurements unless suitable adjustments were made. Also, it was of interest as a possible lead to interactions of stack gas constituents that may occur in the atmosphere.

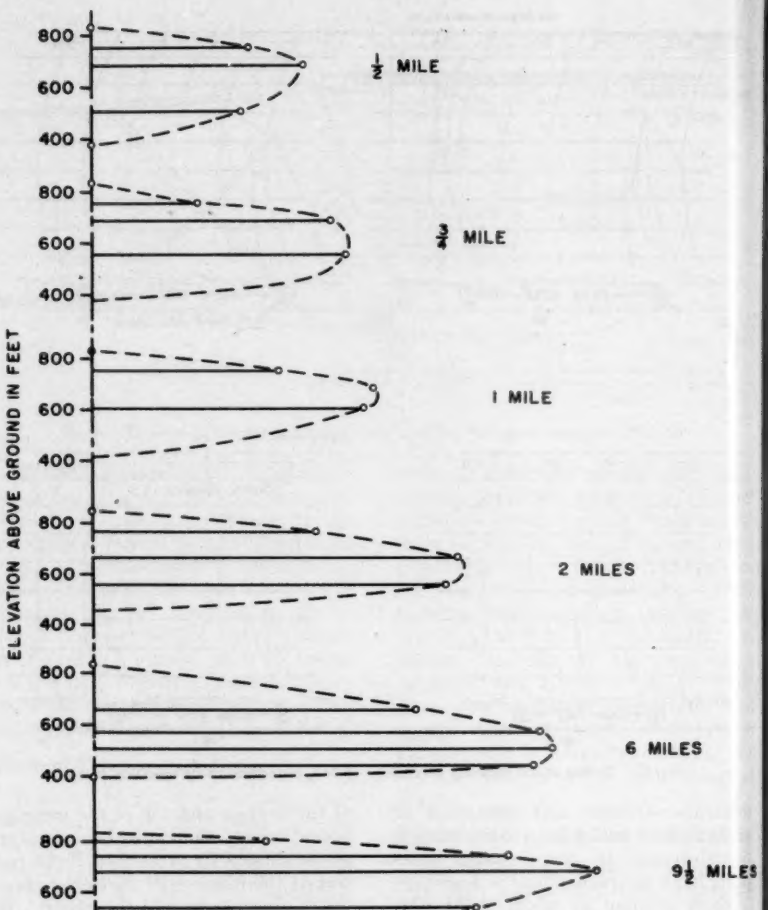

Fig. 6. Cross sections of inversion plume developed from data obtained with Titrilog in helicopter.

Study of representative Titrilog charts indicates that oxidation of SO_2 in the order of 20% to 30% does not appreciably affect the plume dimensions as determined from these charts. Even though oxidation may not be uniform in the plume, the relation of the peak to the average concentration in the plume was found to be relatively constant. Thus, values of n, Cy, and Cz derived from the plume width, depth, and ratio of peak to average concentration should be reasonably accurate. With these values and emission data, concentration of total SO_2 including the oxidized portion in the plume can be computed. Appropriate adjustments for oxidation would yield actual SO_2 concentrations.

One possible explanation for the apparent "loss of SO_2" is that sulfur dioxide might be converted in the atmosphere to sulfur compounds which would not be recorded by the Titrilog. To check on this possibility facilities were constructed in the latter half of 1959 for the controlled dilution and cooling of flue gas with concurrent sampling and analyses to measure the extent of oxidation of sulfur dioxide. In this study air aspirators conveyed gas directly from a steam plant flue through a short heated conduit into a large trailer where moderate control of dilution, detention, and cooling was possible. Concurrent measurements with scrubbers, Thomas autometers, and Titrilog, and sampling of particulates were employed in an effort to determine rates of SO_2 oxidation. Data

Table II—Summary, Principal Data, Inversion Dispersion Tests

Date, 1957	Dist., Miles	Time	Units Operating	Plume Dir.[a]	Approx. Elev.[c]		Plume			SO_2 Concentration[d]			Wind Speed		Lapse[e] °F/1000 Ft
					Elev.[b]	Top	Bottom	Width	Depth	Peak	Av	Time Av	Ground	In Plume	
9/24	1/2	0636	2, 3, & 4	84	680	830	370	1660	460	18.1	8.4	7.0	3.1	9.8	13.8
	3/4	0649	2, 3, & 4	84	680	830+	370	1856	460	17.1	6.8	5.7	2.8	9.9	12.1
	1	0700	2, 3, & 4	84	680	830	410+	2188	420	17.0	7.3	6.3	2.4	10.0	10.3
	2	0716	2, 3, & 4	84	660	845	445	2837	400	10.3	5.0	4.3	2.6	10.0	7.9
	6	0741	2, 3, & 4	84	660	830	390	3441	440	7.9	3.3[f]	3.3[f]	3.1	10.1	2.3
	9 1/2	0801	2, 3, & 4	84	680	840	360	3848	480	5.3	2.0[f]	2.0	2.8	10.0	0
9/25	1/2	0655	2, 3, & 4	3	720	1080+	550	1026	530	29.8	12.7	11.5	2.2	6.2	15.7
	3/4	0704	2, 3, & 4	3	820	1080	540	1041	540	23.5	10.3	9.6	2.2	6.1	13.7
	1	0645	2, 3, & 4	3	740	1140	565	1192	575	21.4	8.0	6.3	2.2	6.3	15.9
	2	0740	2, 3, & 4	3	800	1200	625	1373	575	11.5	5.6	5.2	2.2	5.8	9.9
	8	0752	2, 3, & 4	3	1080	1200	575	2173	625	5.4	2.7	2.4	2.2	5.7	6.8
9/26	1/2	0623	2, 3, & 4	15	670	920	370	875	550	25.4	11.9	10.4	2.2	11.8	11.6
	3/4	0631	2, 3, & 4	15	680	950	425	1328	525	24.3	10.8	9.0	2.2	11.9	11.2
	1	0638	2, 3, & 4	15	680	950	435	2037	515	15.4	7.2	6.0	2.2	11.5	10.4
	2	0657	2, 3, & 4	15	600	950	390	2248	560	8.7	4.3	3.8	2.2	10.9	9.8
9/27	1/2	0637	2, 3, & 4	39	720	965	415	1117	550	16.1	6.4	5.6	3.5	11.5	5.0
	3/4	0647	2, 3, & 4	39	750	1000	350	1418	650	16.9	6.0	4.7	3.7	11.8	3.6
	1	0657	2, 3, & 4	39	720	1000	280	1494	720	17.5	6.0	5.4	4.0	11.9	2.2
	2	0707	2, 3, & 4	39	750	1025	275	2233	750	10.5	3.6	3.1	4.2	11.9	1.5
	8	0737	2, 3, & 4	39	740	1000	180+	4904	820	3.7	1.5	1.3	4.4	11.3	−1.4
10/7	1/2	0638	1, 2, 3, & 4	89	750	1150+	300	1388	850	22.7	10.1	9.5	5.1	9.1	16.3
	3/4	0646	1, 2, 3, & 4	89	750	1160+	410	1554	750	19.8	8.9	7.8	5.3	8.9	15.7
	1	0655	1, 2, 3, & 4	89	700	1260+	390	1766	870	20.7	8.0	7.0	5.5	8.8	16.1
	2	0703	1, 2, 3, & 4	89	720	1300+	475	2113	825	13.6	6.1	5.6	5.4	8.8	15.3
	10 1/2	0809	1, 2, 3, & 4	89	850	1050	650+	5116	400	3.7	1.5	1.4	2.7	10.3	1.6
10/8	1/2	0805	1, 2, 3, & 4	67	1300	1410	630	1147	780	20.3	8.7	8.0	1.0	5.7[g]	0.7
	3/4	0757	1, 2, 3, & 4	67	1350	1485	585	1403	900	13.6	6.0	5.9	1.0	5.7[g]	0.7
	1	0748	1, 2, 3, & 4	67	1050	1490	540	1464	950	18.1	7.0	5.8	1.5	5.6[g]	3.9
	2	0734	1, 2, 3, & 4	67	1000	1540	590	1750	950	14.8	5.9	5.5	1.9	5.5[g]	6.4
	9	0638	1, 2, 3, & 4	67	560	900+	360	5749	540	10.8	4.1	3.7	3.4	5.1	21.4
10/9	1/2	0712	1, 2, 3, & 4	74	950	1300	600	1660	700	19.1	10.3	8.7	2.7	6.0	13.4
	3/4	0720	1, 2, 3, & 4	74	1050	1350+	450	1509	900	21.6	9.0	7.9	4.6	5.8	10.5
	1	0731	1, 2, 3, & 4	74	850	1300	400	2082	900	18.4	8.9	7.7	2.5	5.4	10.9
	2	0744	1, 2, 3, & 4	74	900	1350	450	2384	900	16.9	5.7	5.4	2.5	5.6	9.0
	9	0618	1, 2, 3, & 4	74	550	740	450	4904	290	9.5	3.6	3.4	3.3	8.2	25.4
10/10	1/2	0740	1, 2, 3, & 4	74	850	1350	670	1841	680	20.5	7.9	4.4	4.0	6.7	−4.4
	1	0727	1, 2, 3, & 4	74	850	1350	650	2792	700	5.3	2.6	2.3	3.6	7.0	−3.6
	2	0708	1, 2, 3, & 4	74	1000	1300	480	4104	820	4.1	1.4	1.2	3.5	7.2	−1.8

[a] Degrees off of line of stacks.
[b] Elevation of flight where maximum concentration recorded.
[c] Approximate elevation of observed top and bottom of plume; + indicates a trace or more of SO_2 concentration was recorded.
[d] Peak—The maximum concentration recorded in the plume. Av.—The average concentration determined from the curves of maximum transects at each flight elevation. Time av.—The average concentration of all flights in section.
[e] From 4 ft to elevation.
[f] No repeat flights made.
[g] Estimated.
Note: Elevations in feet above plant level, plume dimensions in feet, SO_2 concentrations in ppm by volume, and wind speed in miles per hour.

have not been fully analyzed but preliminary appraisal indicates that the rates of loss of sulfur dioxide through oxidation observed in the dilution chamber are in the same order of magnitude as those observed in the plume.

Measurements of rates of oxidation of SO_2 in the atmosphere by aerial sampling are planned. Possibilities for measuring other materials in the plume, such as CO_2 and particulates, are being investigated as a means for checking dispersion parameters determined from SO_2 measurements with the Titrilog.

Summary

The Tennessee Valley Authority in co-operation with the U. S. Public Health Service initiated in July 1957 a full-scale study of diffusion of stack gases from large coal-burning power plants. Three-dimensional measurements of dispersion are made by aerial sampling of SO_2 with a Titrilog operated in a helicopter. This report describes equipment and sampling plans. Data from sampling of eight inversion plumes, along with the results of preliminary analyses of these data, are presented. Apparent losses of SO_2 from the plume with time and distance from the source are cited. Preliminary investigations of this finding by means of controlled dilution and cooling of flue gas pointed to oxidation of SO_2 as a possible explanation.

Acknowledgments

The authors gratefully acknowledge the contributions of the numerous persons and organizations participating in the study. R. A. McCormick and others of the Meteorology Group of the Public Health Service, Robert A. Taft Sanitary Engineering Center, provided assistance in planning the sampling procedures and in field activities. Minor Graves, Superintendent of the TVA Colbert Steam Plant, and his staff, provided routine and special plant operational data. It would have been impossible to achieve the desired precision in sampling operations without the enthusiastic co-operation of Kirk Vandeventer, Helicopter Pilot, TVA Transportation Branch. For special equipment development and installation, the invaluable assistance of R. E. Sparkman of the TVA Division of Health and Safety is acknowledged. Others of the TVA Division of Health and Safety making major contributions to

(*Continued on p. 96*)

Table III—SO_2 Flux: Relative Values

Date	Distance, Miles								
	1/2	3/4	1	2	6	8	9	9 1/2	10 1/2
9/24/57	5.0	4.6	5.3	4.6	3.9	—	—	2.9	—
9/25/57	5.4	4.5	4.3	3.5		3.1	—	—	—
9/26/57	4.5	7.5	5.9	4.2	—	—	—	—	—
9/27/57	3.1	4.3	4.6	4.7	—	4.7	—	—	—
10/7/57	9.4	7.4	9.6	8.3	—	—	—	—	2.4
10/8/57	6.1	5.9	7.6	7.7	—	—	8.8	—	—
10/9/57	9.4	9.6	13.1	9.5	—	—	3.6	—	—
10/10/57	7.8	—	5.0	3.7	—	—	—	—	—

Monitoring of FLUORIDE CONTENT of Air, Water, and Vegetation*

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In 1956, American Cyanamid Company started design of a 600 ton per day Triple Superphosphate Plant (TSP) to be constructed at Brewster, Fla. The Environmental Health Section of the Central Medical Department worked very closely with the Engineering and Construction Division, and with Brewster plant management and production personnel to design pollution control measures into the blueprint specifications of the new plant.

One year before the TSP plant was constructed, a sampling study was begun which was designed for air and stream monitoring continuously for five years. During the first year, background levels of fluoride were determined by appropriate collection and analytical techniques. This comprehensive air and stream monitoring program was continued after plant startup in 1957. By this means, an evaluation was made of the effectiveness of controls designed into the plant in the blueprint stage.

The comprehensive monitoring program consists of:

1. Continuous atmospheric monitoring for particulate fluorides.
2. Continuous atmospheric monitoring for gaseous fluorides.
3. Continuous stream sampling.
4. Observation of fluoride-sensitive, experimental plantings.
5. Sampling of native vegetation.
6. Collection of meteorological data, i.e., wind direction and speed, relative humidity, ambient temperature, thermal lapse condition to 225 ft elevation, rainfall, and barometric pressure.

Manufacturing Process—General

The following is a brief description of the manufacturing process: there are two main stages of production—production of phosphoric acid and the production of TSP. In the production of phosphoric acid, sulfuric acid and phosphate rock dust are fed simultaneously and continuously into large, rubber-lined steel tanks where they are vigorously mixed and circulated for about six hours. During this mixing, a chemical reaction takes place which results in the formation of phosphoric acid and calcium sulfate or gypsum. The gypsum crystals are removed from the liquid phosphoric acid by filtration. This is a continuous operation in which the acid-gypsum slurry is pumped from the reaction tanks into shallow pans mounted on a moving endless belt. The bottom of each pan consists of an acid-resistant, synthetic filter cloth. As the pans travel over a vacuum system, the gypsum is retained on the filter cloth and the acid is drawn down through the gypsum filter cake and diverted into a tank for storage. After the pans pass the vacuum section, high pressure water sprays sluice the gypsum cake into a launder (trough) that conveys the resulting slurry to an impounded gypsum disposal pond.

The phosphoric acid produced by the above chemical reaction is weak, approximately 32% P_2O_5 and must be concentrated before use in the production of TSP. Steam heated rubber-lined vacuum evaporators are used for this purpose. The water is evaporated as steam vapor until the acid strength reaches 54% P_2O_5. At this point, the acid is stored for subsequent use in the manufacture of TSP.

In the second stage, TSP (monocalcium phosphate) is produced by reacting concentrated phosphoric acid with phosphate rock dust. Dust and acid are fed continuously through a stationary cone mixer, onto an endless rubber reaction belt, where the initial chemical reaction takes place. At this point, the acid and dust form a viscid slurry. As it moves up the reaction belt, the slurry forms a moist, cellular cake. A hard crust forms on top of the cake. From the setting belt, the product drops onto a shuttle conveyor which distributes it in a large "curing" building, where it is stored for approximately 30 days. During this period, the chemical reaction proceeds to completion and a soluble concentrated phosphate fertilizer (TSP) is produced that is readily assimilated by plants.

Florida phosphate rock is a non-crystalline phosphorite consisting principally of fluorapatite (a complex of tricalcium phosphate and calcium fluoride). In addition, phosphate rock contains many impurities including: organic matter, iron and aluminum oxides, carbonates of lime and magnesium, and small amounts of sodium, potassium, chromium, copper, uranium, etc.

In the production of phosphoric acid and TSP gaseous fluorides in the form of HF, SiF_4, and H_2SiF_6 are released as a by-product.

Pollution abatement control devices were installed in the Brewster plant at the various steps in the process, where fluoride evolution was anticipated.

Environmental Conditions

Topography

The Brewster plant is located in the southern part of Polk County, Fla. Polk County is almost in the center of the peninsular part of Florida and has three outstanding physiographic features:

1. The comparatively high rolling upland and lake region in the central and northeastern parts.
2. The flatwoods region bordering the uplands.
3. Stream valleys along Peace, Withlachoochee, and Kissimmee Rivers

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

and their tributaries.

The stream valleys are comparatively shallow, with very gradual slopes from the bordering flatwoods to the marsh, swamp, or overflow land through which the poorly defined channel meanders. Most of the slopes range from 15 degrees to 25 degrees. The sea level elevation ranges between 50 ft and 324 ft. The Brewster plant is located in a flatwoods region west of the uplands.

Climate

Polk County climate is subtropical. The temperature is moderated by numerous lakes that are scattered through this section of the peninsula and by winds that sweep across the State from the Gulf and the Atlantic Ocean. A temperature of 101°F is an extreme. A temperature of 90°F is reached occasionally between February and December. The mean for the summer months is about 80°F. Freezing temperatures occur only a few times during the year.

The influence of the atmospheric circulation and the relatively high temperatures between February and December produces a large number of rain clouds. The average summer rainfall at Brewster is about 20 in. The combined average spring and summer rainfall is about 36 in. During the fall and winter months, the weather is characterized by bright, sunny days with an average rainfall of about 21 in. The average annual rainfall based on a three-year average is about 57 in.

The wind direction is greatly affected by the local thunderstorm activity during the warm months. The pattern during these months is characterized by shifting wind direction with a fluctuating velocity. The predominant wind direction, however, is from East to West.

Vegetation

In the area around the plant there are predominantly four soil types: Portsmouth fine sand, Leon fine sand, Norfolk fine sand, and St. John's fine sand. The common types of vegetation found on these soils are slash and long-leaf pine trees and saw palmetto and wire grass. Occasionally on the low knolls, dwarf oak, upland willow oak, and scattered long-leaf pine can be found. There are a few citrus groves within a five-mile radius of the plant.

Sampling Method

Atmospheric Sampling

Air samples are collected to determine the gaseous and particulate fluoride content. Dust fall stations are utilized to evaluate the settleable solids and washout effect of the rain.

Four continuous dynamic air sampling stations are positioned around the plant. These stations are located at the following positions relative to the TSP plant:

No. 1—One mile West
No. 2—1100 feet South-Southwest
No. 3—1000 feet North-Northeast
No. 4—4500 feet Northeast.

The locations were chosen on the basis of prevailing wind direction, location of other plants in the area, and accessibility. The sampling devices are located in a steel cabinet mounted on a post. The air sampling inlet is located about six feet above the ground. It is protected from rain and dust impingement action of the wind by a metal guard that extends out and down over the inlet opening. The sample site locations are in areas that have a heavy ground cover of permanent vegetation and are away from any immediate area of influence such as unpaved roads of farms.

The dynamic air sampler is a device that collects simultaneously particulates in excess of 0.2 mμ in size and gaseous fluorides. The particulate collector consists of a filter holder and a membrane filter. The gas scrubber is constructed of a two-liter side-arm vacuum flask and a sintered glass impinging tube. 750 ml of 0.1 N NaOH solution is used as a collecting medium. A dry gas meter is used to measure the air flow rate. A Gast carbon vane pump is used to take the sample. Air samples are taken over a seven-day period. In order to facilitate the program and minimize the chance of contamination, a duplicate set of filter holders and flasks is utilized. The flask and filter holder are cleaned and prepared in an air-conditioned laboratory. Quick-disconnect polyethylene connectors are utilized to facilitate the transfer of sampling devices. The field transfer of the equipment takes about three minutes at each station.

In evaluation of particulate fluoride fall-out and wash-out effects of rainfall, 18 static type samplers are utilized. These samplers are located at various distances and directions from the plant. The locations were carefully chosen and consideration was given to: wind direction, distance from the TSP plant and other plants, adequate ground cover, activity such as farming and traffic, unpaved roads, and accessibility.

One static sampling station is located 20 miles west-southwest of the plant. This station is utilized as a control, since it is located in an area of minimum influence by all plants in the general area.

The static samplers consist of a plastic bucket-type collector positioned in a metal container mounted on top of a seven-foot post. A small amount of water is kept in the plastic collector to minimize loss by wind action. Copper sulfate is added to the water to inhibit the growth of algae and other microorganisms. Sample collection is done on a monthly basis. Two static sampling stations were set up to evaluate the possible effect of locally generated dust on collection rates at seven-foot levels. At each station, a static sampler is located at a level of seven and 30 feet above the ground. One sampler is located 4000 feet southwest of the plant and the other at the control site, 20 miles southwest of the plant. The results of the sampling, which cover the period of approximately one year, show that local wind action, farming practices, and automobile traffic do not significantly affect the dust fall as determined by measurements at the 30-foot height. It is well established that dust fall rates 30 feet above the ground are not significantly affected by dust generated locally through human and natural activities.

Stream Sampling

Four water sampling stations are used to monitor the plant effluent in the South Prong of the Alafia River. Two of the sampling stations are electrically operated and collect a 25 ml sample every 15 minutes. The other two stations are hydrostatically operated and collect about 15 ml of water every five minutes. These small samples are collected over a period of one week and stored in a large plastic bottle. A representative portion of the large composite sample is taken at the end of each week for chemical analysis. The sample is analyzed for pH, turbidity, and fluoride content.

Meteorological Equipment

A meteorological sampling station was located at a convenient site near the TSP plant. The following chart recording instruments are used to obtain meteorological data on: relative humidity, wind direction and speed, ambient temperature, and barometric pressure. A temperature lapse rate recorder is installed on an abandoned stack located approximately one mile from the plant. Temperature sensing elements are mounted at the ground and at the top of the stack, which is 225 feet high. A dip stick rainfall gauge is located near the Analytical Laboratory, which is about 0.5 mile from the plant.

The wind direction and speed indicator is mounted in an area where representative wind currents can be measured. Readings from this instrument have been checked with those from a similar instrument located at a position six miles to the north. A comparison of the data from both instruments shows an almost identical recording pattern. For the sake of wind rose compilation, the results are identical. A sling psychrometer is used to

Table I

Direction from Plant	*Distance in Miles*
North	1, 1 1/2, 2
Northeast	4
East	1/4, 1/2
Southeast	1/4, 1/2, 1, 2, 4
South	1/4, 1/2, 1, 2, 4, 6, 8, 10, 50, 100
Southwest	1/4, 1/2, 1, 2, 4, 6, 8, 10
West	1/4, 1/2, 1, 2, 4, 6, 8, 10, 25
Northwest	1/4, 1/2, 1, 5, 7

check the calibration of the relative humidity and ambient temperature recorder twice each week.

Experimental Plantings

Two fluoride-sensitive indicator plants, gladiolus and buck wheat, were planted in a garden plant to determine if they could be used in the vegetation surveillance studies. The garden site was located at a distance of 0.7 mile west of the plant. The indicator plants were chosen because they are adversely affected by very low concentrations of gaseous fluoride (2–3 ppb). The air concentrations at this location exceeded these levels at times, and, therefore, the use of these plants as indicators proved to be unsatisfactory. The use of experimental indicator plants was not pursued after this experience.

Vegetation Sampling

The vegetation sampling program has been accomplished in two phases. The first sampling was exploratory and was done on a transect basis, spokewise around the plant. Vegetation sampling sites were located as shown in Table I relative to the Triple Superphosphate Plant.

The extent of significant plant influence was established by this phase of the sampling program.

In the second phase of the program, a combination grid and spoke sampling pattern was then established to obtain more detailed knowledge of the conditions around the plant. The grid pattern encompassed an area six miles to the west, three miles to the north and east, and two miles to the south of the plant. Vegetation sampling sites were located on one mile centers throughout the grid pattern. The sample sites described under the exploratory sampling pattern above, and located outside the area covered by this grid pattern, were retained in this sampling program. The spoke pattern, superimposed over the grid, covered an area five miles to the south and ten miles to the west of the plant.

Control sample plots were selected at distances of 50 and 100 miles to the south of the plant. The general conditions of soil type, type of vegetation, climate, rainfall, etc., are the same for the control plots as for the sample sites around the plant. Fluoride analyses were made on soil at the control site, and on various types of vegetation.

Wire grass (Aristida spp. and Sporobolus spp.) was selected as the indicator plant because it could be found at practically all of the chosen sampling sites. This selection was made after carefully analyzing the growth characteristics and comparing the results of fluoride analyses with those of the other natural vegetation growing at the same location. Wire grass is a narrow-leaf grass whose physical structure gives it the name wire grass. Because of the structure of the grass, it would support a minimum amount of dust on the outside and it can be washed for analysis very easily.

It was established through comparative sampling, that the fluoride levels in washed broad leaf grasses are consistently about 25% higher than those found for washed wire grass at the same site per unit of weight.

At each sampling site, approximately 80–100 grams of wire grass are collected in one composite sample. This composite is later divided to provide a washed and an unwashed sample for analysis. Recently matured foliage from the center of each wire grass stool is gathered together in one hand and cut from the plant at a point four to six inches from the ground. Eight to ten plants are sampled at each site to obtain a composite sample. Some older, dead foliage is generally included in each cutting. All foliage that is dead at the cut surface is removed to assure uniformity in sample collection.

Polyethylene bags of 0.0015 gauge, 9 1/2-in. x 18-in. in size, are used to transport the samples to the Preparation Room and Laboratory. The bags are coded with a chine marking pencil and the code is entered on a field data sheet along with appropriate comments, including observations on any unusual condition that might exist. The samples are kept shaded while in transit to the Preparation Room.

A separate room was specially prepared for sample preparation. The room, 8 ft x 8 ft in size, is windowless. The door is weather stripped to make it as dustfree as practicable. A one-ton air-conditioning unit constantly filters the air inside the room. All work surfaces are constructed of stainless steel.

Prior to sample preparation, the floor of the room is moistened with water and all work surfaces and wash basins are thoroughly washed with a detergent solution, rinsed, and allowed to air dry.

Upon receipt, the field sample is inspected and the average length of foliage, degree of necrosis, and other pertinent observations are recorded. The sample is then divided into two equal parts. One portion is washed before further processing and the other is processed unwashed. All samples are ground in a Standard Model No. 3 Wiley Mill using a 1.5 mm mesh screen. First the unwashed sample is ground and then the mill is carefully cleaned before grinding the washed sample.

In the washing procedure, the grass sample is swirled back and forth 20 times in a basin containing 10 gallons of water and six to eight cc of liquid detergent (low fluoride content). This procedure removes the adhering particulate matter from the grass. In the preparation of special samples for analysis, i.e., citrus foliage, the leaves must be hand washed, and in most cases scrubbed lightly with a bristle brush, to remove the adhering particulates.

After the particulate material has been washed from the sample, it is rinsed in a basin of clean water to remove the detergent solution. Finally, the sample is rinsed with a clean water spray. The excess water is shaken off, and the foliage spread on a work table until the surface water has evaporated. It has been demonstrated by the use of a magnifying scope that this procedure will remove most of the adhering particulate matter from the samples.

Samples Go to Lab

After preparation of the samples is completed, they are delivered to the Laboratory where the analytical work is started immediately. The number of samples collected during a day is determined by the capacity of the Analytical Laboratory. At no time are samples collected and stored, in any form, for future analysis. We have investigated various methods for storage of samples including: quick freezing, lime slurry, storage in a sealed glass jar, and a combination of the two methods. All these methods have been rejected because it was shown that fluoride is lost during storage. The loss, while usually with 10 to 15% for periods up to 10 to 15 days, was not found to vary in a predictable manner, and, therefore, storage of the samples was not employed. The Analytical Laboratory equipment and procedures were expanded to handle a larger volume of samples more efficiently.

Soil samples were collected at representative sampling sites to determine the fluoride concentration in the top six inches of soil. These data were used in the final evaluation of the results.

Analytical Methods

Sample Preparation

The methods utilized in sample preparation vary depending on the physical nature of the sample. After sample preparation, the basic evaluation of fluoride content is the same for all samples. Technique of sample preparation can significantly affect the final result of the analysis. It is very important to validate each step in the procedure to be sure that the analytical technique is valid. The following is a brief description of the sample preparation procedure for the various samples analyzed by the Laboratory. Following this section on sample preparation, a discussion will be made of the general analytical procedure utilized in the estimation of the fluoride content of all types of samples.

Vegetation

Two aliquots of each sample are weighed (approximately 10 g) in cleaned and stoppered weighing bottles. One sample is dried in an oven at 105°C for 24 hours to determine the moisture content. The other sample is transferred to a clean platinum evaporating dish (50 ml capacity). One gram of low fluoride (1–3 ppm F) slaked lime is added. The mixture is slurried with water, using a clean glass stirring rod.

The limed sample is placed under infrared light which reduces the mass to a char. The platinum dishes containing the charred sample are then placed in a muffle furnace where it is held at 600°C until ashing is complete, as indicated by a white or light gray ash. Calcination of samples in the presence of lime and large amounts of silica may cause conversion of fluorine to a form refractory to the distillation procedure in the final assay. In order to break up this refractory complex, the sample is fused with 5.0 g of sodium hydroxide pellets over a burner for 15 minutes. After fusion, the molten mass is allowed to cool and then it is dissolved by a small amount of water in a beaker on a hot plate. The dissolved sample is then quantitatively transferred to the distillation flask for final assay.

Soil

The soil sample (approximately 200 g) is dried in an oven at 105°C for 48 hours to remove the free moisture. It is then ground in an attrition mill.

The large powdered sample is then rolled, quartered, and a 20 gram representative portion is taken for fluoride analysis. If the fluoride content of the sample is estimated to be below 500 ppm F, or if there is no basis to make an estimate of concentration, a one gram sample is weighed for analysis. If the concentration is estimated to be greater than 500 ppm F, a 0.5 gram sample is used. The weighed sample is quantitatively transferred to the fluoride distillation flasks (modified Claissen) with water and 75 ml of concentrated sulfuric acid is cautiously added. The fluoride is distilled from the sample by means of steam and a pot temperature of 165°C ± 3°C. Approximately 500 ml of distillate is collected and maintained alkaline to phenolphthalein with sodium hydroxide. The distillate is made to a known volume and an aliquct transferred to a clean distillation flask for final assay.

Air

Filter Sample. The filter membrane is carefully transferred from the filter holder to a platinum evaporating dish. Two ml of distilled water and one gram of low fluoride slaked lime are added. The lime is slurried and brought into contact with the entire surface of the filter. The filter is then reduced to a char under infrared light. A muffle furnace is used to ignite the char for ½ hour at 600°C. The ash is slurried with water and quantitatively transferred to the distillation flask for final assay.

Scrubber Sample. The sample is adjusted to a known volume and one-half of the sample is then evaporated on a hot plate to a volume of approximately 40 ml. The sample is alkaline to phenolphthalein and should be kept in this condition to prevent the loss of fluoride during the evaporation. The concentrated sample is then quantitatively transferred to the distillation flask for final assay.

Water

There are no special preparation procedures for the determination of fluoride in water samples. A 50 ml sample is transferred to a Claissen flask for final assay.

Analytical Procedure for All Samples

Reagents

a Calcium Oxide—powdered, low fluoride content (1–3 ppm F) Victor Chemical Company, Chicago, Illinois.

b Hydrochloric Acid (0.05 N) should be prepared as a standard solution. The normality should be the same as for the standard sodium hydroxide.

c Perchloric Acid—70% by weight. $HClO_4$.

d Phenolphthalein Indicator—0.5% solution in 60% ethyl alcohol and water mixture.

e Silver Perchlorate Solution. Dissolve crystals in as small a volume of distilled water as possible. Keep stoppered and stored in a brown bottle.

f Alizarin Red-Strong (Sodium Alizarin Monosulfonate) solution, 0.80 g per liter of water.

g Alizarin Red (Sodium Alizarin Monosulfonate) solution, 0.01 g per liter of water. The solution described under *f* above can be used to prepare this solution.

h Sodium Fluoride Stock Solution. (1 ml = 1.00 mg F). Prepare by dissolving 2.2105 g of 100% sodium fluoride in a liter of distilled water.

i Sodium Fluoride Standard Solution. (1 ml = 0.01 mg F). Prepare by quantitative dilution of the solution, described under *h* above.

j Sodium Hydroxide Standard Solution (0.05 N). This should have the same normality as the hydrochloric acid described under *b* above.

k Thorium Nitrate Standard-Strong Solution (1 ml = 1.9 mg F). Dissolve 13.80 g of thorium nitrate tetrahydrate ($Th(NO_3)_4 \cdot 4H_2O$) in a liter of distilled water. St ndardize against the standard sodium fluoride reagent stock solution described under *h* above. To be used for the direct titration of fluoride samples.

l Thorium Nitrate-Weak Solution (0.25 g per liter). To be used in the back titration procedure for the estimation of small amounts of F.

Distillation of Samples

In the methods of sample preparation described above, the different types of samples were processed to the stage where the sample was introduced into the modified Claissen flask. At this stage, the slurry is alkaline. The chlorides are precipitated by the addition of the silver perchlorate solution dropwise. When chlorides are precipitated in the alkaline state with silver perchlorate, a brown silver oxide complex is formed at the end point of the reaction. One ml of silver perchlorate solution is added after the end point is reached to insure complete reaction of all the chlorides present. Three or four glass beads are added to the flask to minimize bumping during the distillation.

The flask is placed on the distillation rack and steam distilled by means of steam from a generator and an electric heater on the "pot" of the still. The distillation temperature is controlled at 135° ± 3°C. At least 200 ml of distillate is collected at the 135°C temperature. If the samples contain excessive quantities of gelatinous silica, 500 ml of distillate are collected. Continued use of the Claissen flask will cause the inside of the pot to become etched. This condition, if excessive, will allow the fluorides to combine with the glass and be released very slowly in the distilla-

tion step. The flasks are replaced when recovery check analyses show that the fluoride "holdup" in the flask is greater than 5%.

Titration of Fluoride

For distillates that contain relatively high fluoride content (0.05–10 mg F) in the total sample, a direct titration can be performed in a porcelain crucible using the Alizarin Red-Strong solution as the indicator and the standardized thorium nitrate-strong solution.

Pipet an aliquot of the distillate into a 500 ml porcelain crucible and make to 200 ml with water. Add one ml Alizarin Red-Strong solution. Adjust the pH of the solution by the use of sodium hydroxide solution to the pink color end point of the indicator. Then add four ml of 0.05 N HCl and titrate to a faint pink color with the standard thorium nitrate solution. From the ml of standard thorium nitrate reagent used, the equivalent fluoride concentration can be calculated.

For distillates that contain less than 0.05 mg F in the total sample, a double titration procedure is used to estimate the fluoride content. A 25 ml aliquot is placed in one of a matched set of high form Nessler tubes. (A smaller aliquot is taken if the fluoride concentration in the aliquot exceeds three micrograms of F.) One ml of (0.01 g/l) Alizarin Red indicator is added. The solution is then diluted to approximately 45 ml with water and the pH adjusted by titrating the solution with the 0.05 N NaOH solution. When a faint pink color has been reached, the volume of NaOH used is noted. The solution is discarded and another 25 ml aliquot is added to a clean Nessler tube and one ml of the (0.01 g/l) indicator is added. The volume is adjusted to approximately 45 ml with water and HCl 0.05 N is added to give the resultant solution an equivalent pH of two ml of 0.05 N HCl. The sample is then titrated with thorium nitrate-weak solution, to a peach blossom pink end point. A distilled water blank is prepared by adding 45 ml of water, one ml (0.01 g/l) Alizarin Red indicator and two ml of 0.05 N HCl to a matched Nessler tube. A volume of thorium nitrate solution equivalent to that which was required for the sample is added to the blank. The blank is then titrated to the comparable end point of the sample. From the amount of standard fluoride used, the fluoride content can be estimated for the sample. Reagent blanks are determined throughout the entire procedure, including sample preparation, distillations, and titration for each sample.

Results

Air Samples—Dynamic and Static

Data from these samples had been correlated with plant operating conditions, wind direction, and other meteorological conditions to estimate air concentration of particulate and gaseous fluorides under various conditions. Observations were made on the physical condition of vegetation in the vicinity of the sampling stations and air concentrations were estimated in an attempt to determine whether there was a cause and effect relationship. Additional engineering controls are being installed in the plant and the background air concentrations will be used to evaluate the improved plant operating condition.

Samples of Vegetation

The analytical results of vegetation sampling are affected by a large number of variables, for example: physiological conditions of the plant, such as rate of tissue growth, transpiration rate, etc.; rainfall; amount of sunlight; wind direction; concentration and duration of exposure; and time of day, month, or season of year. For these reasons, it is necessary to interpret the results of vegetation samples with care.

Summary

The phosphate fertilizer industry is one of several industries that emits gaseous fluorides from certain manufacturing processes. There are nine major companies located in the Polk County, Fla., area engaged in the manufacture of various phosphate fertilizers. American Cyanamid Co. was one of the last companies in the area to build a triple superphosphate manufacturing plant. These types of plants emit gaseous fluorides in the forms of SiF_4 and HF as a by-product.

In order to reduce emission of gaseous fluoride to a minimum, certain control measures were incorporated in the blueprint specifications of the new processing plant. A five-year air pollution study was started in 1956 to measure the effectiveness of the built-in control devices. The study, still in progress, includes: continuous monitoring air and water sampling studies, vegetation surveys, and a meteorological monitoring program. Results of the study have been used to determine a fluoride emission rate for the plant that will be consistent with the air pollution laws of the state of Florida and the maintenance of desirable conditions around the plant site. Additional control equipment is presently being installed to accomplish this objective. To date, American Cyanamid Co. has spent one and fourtenths million dollars in the study to set plant operating standards and for pollution control equipment.

The air pollution monitoring program has been an indispensable tool in defining the extent of the problem at Brewster and in determining necessary control measures for maximum production without air pollution.

Acknowledgments

The authors acknowledge with appreciation the efforts of many of their colleagues in American Cyanamid Co. who contributed to this program, both in the Laboratory and Engineering Sections of the Brewster Plant, and in the Central Medical Department, N. Y. Special acknowledgment is due W. R. Bradley, formerly Assistant Director of Environmental Health, Central Medical Department, whose encouragement, aid, and advice have been of inestimable value, and Arthur Crago, Manager of Phosphate Operations, Brewster Plant, without whose continued support this program could not have been sustained.

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A Method for DETERMINING SOURCE REDUCTION Required to Meet Air Quality Standards*

RALPH I. LARSEN, Ph.D., Air Pollution Engineering Research, Robert A. Taft Sanitary Engineering Center, U. S. Department of Health, Education, and Welfare, Cincinnati, Ohio

The California State Department of Public Health was requested by the State Legislature in 1959 to promulgate standards for air quality and auto exhaust emissions not later than February 1, 1960. As one phase of this task, California State Health Department officials requested that Air Pollution Engineering Research of the Public Health Service analyze Los Angeles aerometric data and develop criteria for establishing reduction in pollution levels required to obtain any desired level of air quality.

The methods developed herein are applicable for various pollutants. The examples chosen relate to secondary pollutants or manifestations occurring in photochemical smog (oxidant concentration, eye irritation, and decreased visibility) and to a class of primary pollutants (suspended particulate) occurring in any urban atmosphere.

The State arranged with the Los Angeles County Air Pollution Control District to provide the Public Health Service with about 100,000 punch cards containing Los Angeles aerometric and meteorologic data for years 1955 through 1958. Two stations were selected to be representative of the Los Angeles area: downtown Los Angeles (Station 1) and Pasadena (Station 4). Calculations regarding meteorology and several pollutants were summarized on one punch card per day per station using an appropriate computer program. A second computer program was written to perform correlation and regression analyses for sets of variables from the summary card. The summary cards were also used directly to plot scatter diagrams by a machine method and to calculate frequency distributions.

Previous studies by A. J. Haagen-Smit[1, 2] and others have indicated that auto exhaust is probably the primary source of pollutants which reacts to form photochemical smog. In order to determine the relative atmospheric concentration of the several exhaust components which may cause smog it is sufficient to measure the atmospheric concentration of only one exhaust constituent, providing such a measurement meets the following requirements:

1 The measured constituent should be capable of accurate measurement,
2 it should originate primarily from autos,
3 it should not react readily in the atmosphere.[3]

Carbon monoxide fulfills these requirements. Air pollution source data[3] indicate that approximately 84% of all carbon monoxide emitted to the Los Angeles basin is from motor vehicles. For the downtown Los Angeles area, the value probably exceeds 90%. Thus although carbon monoxide itself does not enter into the photochemical smog reaction, it may be used as an indicator of the relative atmospheric concentration of auto exhaust constituents which do cause smog. Its concentration may be related by correlation and regression analyses to such smog manifestations as oxidant concentration, eye irritation, and visibility reduction. The results of such analyses enable prediction of the degree of reduction of the smog precursor pollutants required to obtain desired improvements in air quality. Such a method was used in this study.

Analytic Methods

All of the basic data were provided

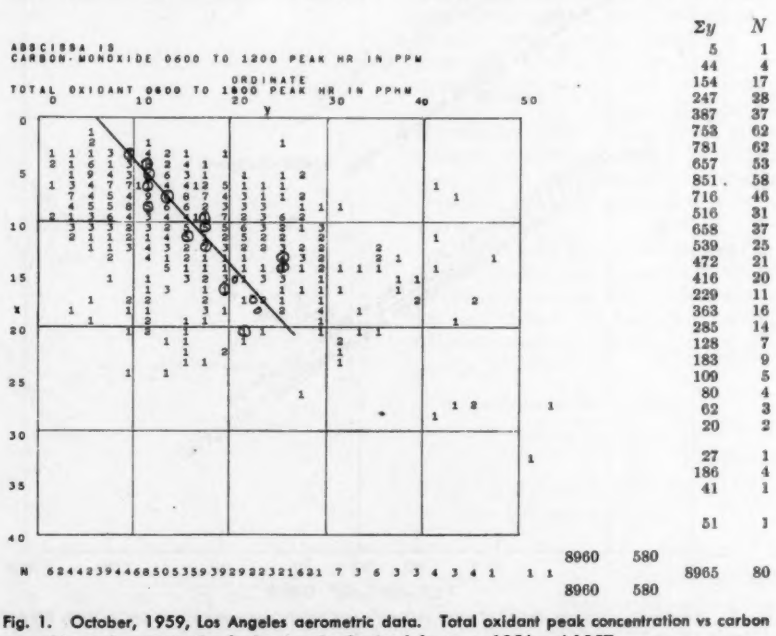
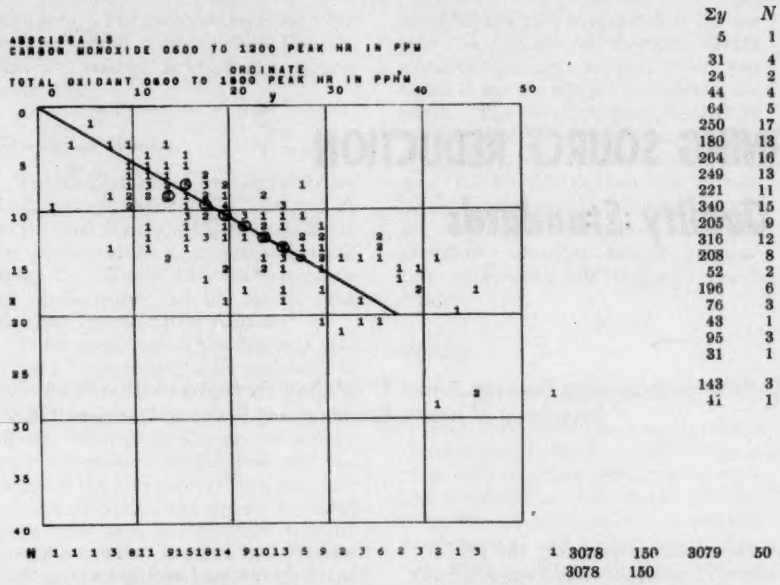


Fig. 1. October, 1959, Los Angeles aerometric data. Total oxidant peak concentration vs carbon monoxide peak concentration for Los Angeles Station 1 for years 1956 and 1957.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.


ABSCISSA IS
CARBON MONOXIDE 0600 TO 1200 PEAK HR IN PPM
ORDINATE
TOTAL OXIDANT 0600 TO 1800 PEAK HR IN PPM
y
N 1 1 1 3 811 91514 91013 5 9 2 3 6 2 3 2 1 3
1 3078 150 3079 50
3078 150

Σy	N
5	1
31	4
24	2
44	4
64	5
250	17
180	13
264	16
249	13
221	11
340	15
205	9
316	12
208	8
52	2
196	6
76	3
43	1
95	3
31	1
143	3
41	1

Fig. 2. October 1959, Los Angeles aerometric data. Total oxidant peak concentration vs carbon monoxide peak concentration for Los Angeles Station 1 for all weekdays with solar radiation greater than 40 Langleys per hour for years 1956 and 1957.

on IBM 80-column punched cards of various formats. IBM 650 computer programs were written to read aerometric, meteorologic, and plant damage data, to calculate mean and peak values, and to punch a card of summary information for each day for each station.

One hundred and twenty bivariate frequency distributions, or "scatter diagrams," similar to Figs. 1 and 2, were produced to show the possible relationship of one variable as a function of another for various time periods and conditions of solar radiation. These were machine-produced using a special control panel devised for the IBM 402 tabulator. The scatter diagram consists of x and y scaled axes, similar to any graph, and a two-dimensional array of numerals each of which indicates the number of sets of data which are located at the co-ordinates of the numeral. For a given scatter diagram sheet, the distribution of x (here plotted in the vertical) is shown on the right margin together with the summation of y values for each x value. The distribution of y appears on the lower edge of the sheet. The median y value for each given x value has been circled and the visual line of best fit has been constructed from the resulting circles.

A computer program was written to calculate arithmetic and geometric correlation and regression between any two variables for various periods of time, location, and condition of solar radiation. Two thousand correlation coefficients and the associated regression lines of best fit were calculated to explore the interrelationships between variables. The summary punched cards were the input to this computer program.

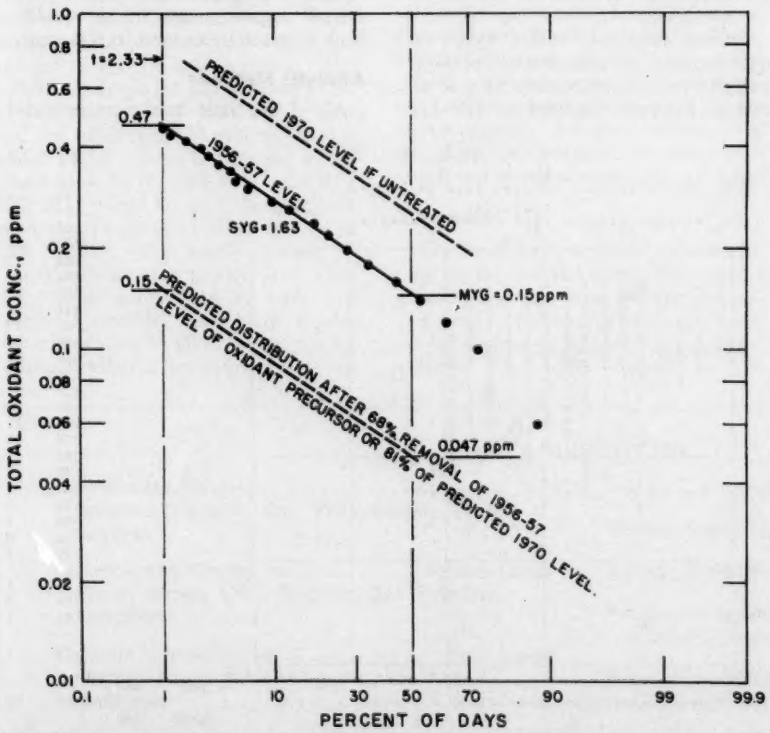


Fig. 3. Frequency of various levels of total oxidant peak hourly concentration at Los Angeles Station 1 during 1956–57.

Results

The purpose of these analyses is to show the frequency of occurrence of various values of oxidant, eye irritation, and visibility; to indicate the equations relating these pollutant effects to concentration of carbon monoxide; and to show the usefulness of this information for predicting removal of precursor, as measured by carbon monoxide, necessary to obtain given levels of improved air quality.

Bivariate Frequency Distributions

Oxidant and carbon monoxide values used for these analyses are the highest hourly average concentrations for the period indicated and are referred to herein as "peak hourly concentrations." Considerable scatter of oxidant as a function of carbon monoxide is demonstrated for downtown Los Angeles if all data are included (Fig. 1). Since oxidant concentration is also a function of solar radiation there is much less scatter if samples taken only during specific limits of radiation intensity are chosen. Still less scatter is exhibited if only samples taken on weekdays are used (Fig. 2). Thus it is seen that oxidant is a function of many variables and that high correlation with carbon monoxide level is obtained by restricting the range of the other variables. Similar results, though not as marked, were obtained at Pasadena. The lower correlation is believed to be due in part to the fact that the measurement of carbon monoxide in Pasadena from 0600 to 1200 is not necessarily an index of expected later oxidant (near 1400) since large quantities of smog precursors are expected to be transported into Pasadena from Los Angeles.

Table I—Correlation and Regression of Oxidant Hourly Peak Concentration, Eye Irritation, and Minimum Visibility

(With CO Mean Hourly Concentration for Weekdays of Third Quarter of Years 1956 and 1957 for Solar Rad. ≥ 40 Langleys/H. for Los Angeles Station 1)

Depend Var. Y	Period	No. of Sets of Data N	Correl. Coeff. r	Regression Line: Slope b	Regression Line: Intercept a	Regression Line: Std. Geo. Error Est. $s_{y \cdot xg}$	Geo. Mean m_{xg}	Geo. Mean m_{yg}	Std. Geo. Deviation s_{xg}	Std. Geo. Deviation s_{yg}
Oxid. Pk.	July-Sept.	89	0.81	0.92	0.028	1.25	9.3	0.215	1.40	1.47
	July	35	0.70	0.84	0.033	1.24	7.8	0.187	1.29	1.35
	August	25	0.76	0.88	0.029	1.31	9.5	0.207	1.43	1.51
	September	29	0.86	1.03	0.022	1.22	11.0	0.261	1.37	1.46
Eye Irrit.[a]	July-Sept.	117	0.63	0.94	0.27	1.56	8.9	2.16	1.65	1.77
	July	40	0.43	0.83	0.37	1.70	7.4	1.95	1.35	1.79
	August	39	0.73	1.02	0.24	1.48	8.9	2.19	1.49	1.75
	September	38	0.73	1.21	0.13	1.48	10.8	2.36	1.41	1.77
Min. Vis.	July-Sept.	81	−0.48	−0.78	14.2	1.64	9.4	2.51	1.41	1.75
	July	31	−0.25	−0.50	7.6	1.66	7.8	2.75	1.30	1.67
	August	23	−0.52	−0.76	13.6	1.61	9.5	2.47	1.45	1.73
	September	27	−0.62	−1.22	43.0	1.64	11.2	2.29	1.37	1.85

[a] Eye irritation is for all values of solar radiation since breakdown for various radiation intervals was not calculated.

Correlation and Regression

An analysis of the various combinations of correlations of arithmetic and logarithmic values of carbon monoxide and oxidant means and peaks indicates that the highest correlation for both arithmetic and logarithmic values occurs when peak values of both pollutants are used. Probability plots (e.g., Figs. 3 and 5) indicate that the variables tend to be logarithmically distributed. Since it is also expected that the regression between variables will be logarithmic, this type of analysis was used.

The relation of the two variables of a logarithmic regression analysis is given by the general equation

$$y = ax^b \qquad (1)$$

For this particular case, y is the value of smog manifestation (oxidant concentration, eye irritation, or visibility) and x is the carbon monoxide hourly peak value and a and b are constants derived for a particular station and relationship. If this equation is to be used to calculate the change in y that will occur with a given reduction in x, the exponent b is the important constant and the value of the coefficient a is immaterial. Regressions of oxidant and eye irritation against carbon monoxide (e.g., Table I) indicate that b tends to assume a value of about 1. For minimum visibility, it is about −1. These values of b were used for the analyses made in this report.

Determining Required Removal of Smog Precursors

The frequency distribution summarized at the bottom of Fig. 1 has been plotted on log-probability paper as Fig. 3. The high oxidant concentrations occurring on 50% or less of the days of 1956 and 1957 appear to fit well, with a median value of 0.15 ppm and a standard geometric deviation of 1.63. This plot may be used graphically to determine required removal of oxidant and its precursors to obtain a given air quality or the required removal may be determined analytically. In the example shown, 68% removal of oxidant precursor is required to reduce the 1956–57 level from 0.47 ppm occurring on 1% of the days to 0.15 ppm. (This has been determined by drawing a line through 0.15 ppm for 1% of the days parallel to the 1956–57 distribution line to intersect the 50% of days abscissa at an oxidant concentration of 0.047, which is 68% reduction of the 0.15 value on the original 1956–57 distribution.)

Similarly, predicted levels of oxidant for any future data, if precursors are not removed, can be determined on the basis of anticipated future gasoline consumption. For instance, for a 1970 level of gasoline consumption equal to 1.7 times the 1956–57 level, the 1970 predicted distribution may be drawn parallel to the original distribution through the 50% abscissa point at an oxidant concentration of 1.7 times 0.15 ppm, or 0.25 ppm. Similarly, estimates of oxidant levels for previous years may also be made.

As previously stated, the required removal of oxidant precursor, as measured by carbon monoxide, may be determined for any date by substitution in the following equation developed in Appendix A:

$$\% \text{ oxidant precursor removal} = 100 \left\{ 1 - \left[\frac{(1956\text{–}57 \text{ gas cons.})(\text{desired oxid. conc.})}{(\text{est. gas cons.})(m_{yg})(s_{yg})^t} \right] \frac{1}{b} \right\} \qquad (2)$$

where m_{yg} = the 1956–57 oxidant geometric mean concentration,

s_{yg} = the 1956–57 oxidant

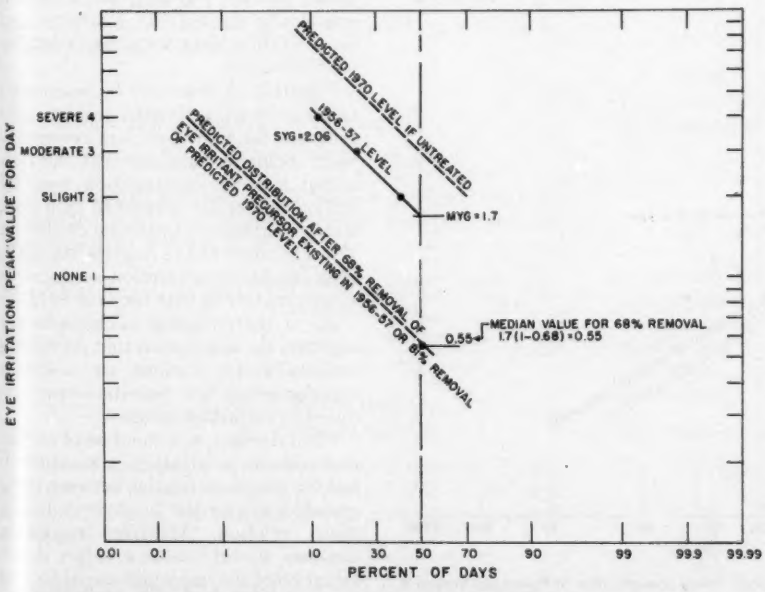


Fig. 4. Frequency of various levels of eye irritation in downtown Los Angeles during 1956 and 1957.

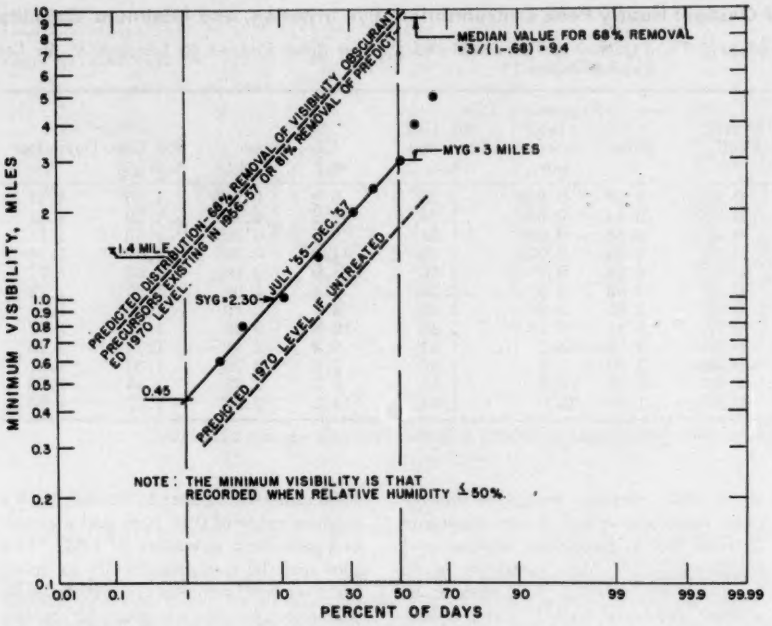

MINIMUM VISIBILITY, MILES
PERCENT OF DAYS
MEDIAN VALUE FOR 68% REMOVAL = 3/(1-.68) = 9.4
MYG = 3 MILES
1.4 MILE
SYG = 2.30
JULY '55 - DEC '57
0.45
PREDICTED DISTRIBUTION-68% REMOVAL OF VISIBILITY OBSCURANTS PRECURSORS EXISTING IN 1956-57 OR 81% REMOVAL OF PREDICTED 1970 LEVEL.
PREDICTED 1970 LEVEL IF UNTREATED
NOTE: THE MINIMUM VISIBILITY IS THAT RECORDED WHEN RELATIVE HUMIDITY ≤ 50%.

Fig. 5. Frequency of various values of daily minimum visibility in downtown Los Angeles from July, 1955 to December 1957.

standard geometric deviation,

t = the number of standard deviations corresponding to the desired frequency of occurrence, and

b = the exponent in Equation (1).

Similarly, for any percent reduction of all eye irritant precursors, the improved irritant level may be determined graphically (Fig. 4) in the manner previously outlined or calculated using the following equation developed in Appendix A:

$$t = \frac{\log\left[\dfrac{(\text{improved irritant level})}{(m_{yg})\left[\dfrac{1-\%\text{ removal}}{100}\right]^{b}}\right]}{\log s_{yg}} \qquad (3)$$

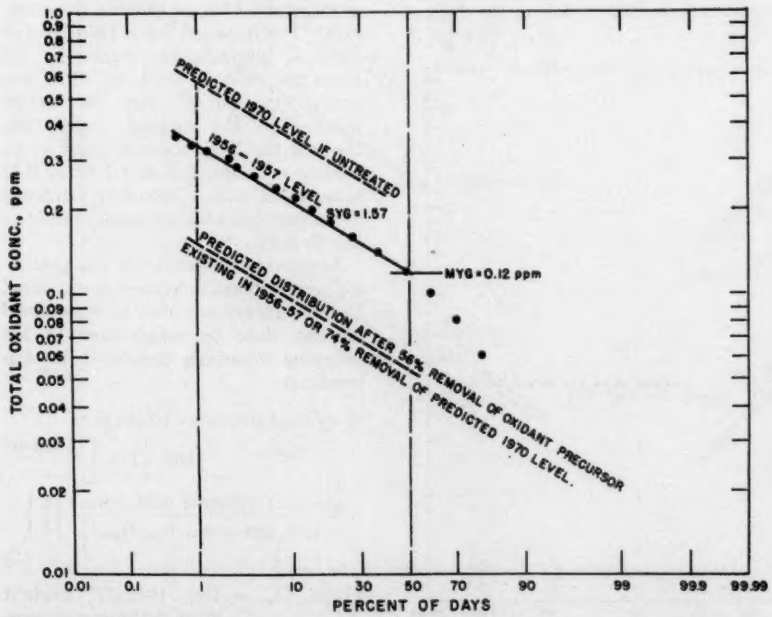

TOTAL OXIDANT CONC., ppm
PERCENT OF DAYS
PREDICTED 1970 LEVEL IF UNTREATED
1956 - 1957 LEVEL SYG = 1.57
MYG = 0.12 ppm
PREDICTED DISTRIBUTION AFTER 56% REMOVAL OF OXIDANT PRECURSOR EXISTING IN 1956-57 OR 74% REMOVAL OF PREDICTED 1970 LEVEL.

Fig. 6. Frequency of various levels of total oxidant peak hourly concentration at Pasadena Station 4 during 1956–57.

where m_{yg} = the 1956–57 irritant geometric mean concentration,

s_{yg} = the 1956–57 irritant standard geometric deviation, and

b and t are as defined previously for Eq. (2).

In a similar manner, for any percent reduction of all visibility obscurants and their precursors the improvement in visibility may be determined graphically (Fig. 5) in the manner previously outlined or calculated using the following equation derived in Appendix A:

$$\text{Improved visibility} = \frac{(\text{vis. geo. mean})\left[\dfrac{1-\%\text{ removal}}{100}\right]^{b}}{(\text{vis. std. geo. dev.})^{t}} \qquad (4)$$

Substitution in Eq. (2), where b and t are as previously defined, indicates that 81% removal of oxidant precursors will be required by 1970 to reduce oxidant concentration in downtown Los Angeles on 1% of the days to 0.15 ppm. This value checks that obtained using the graphical solution. It is determined (using Eq. (3), or the graphical solution using Fig. 4) that a similar removal of all eye irritant precursors (81%) will decrease the frequency of slight irritation from 40% of the days experienced in 1956–57 to 4% of the days in 1970. For this same degree of removal of all visibility obscurants (81%), the corresponding minimum visibility on 1% of the days (as determined by Eq. (4), or graphically using Fig. 5) is predicted to rise from 0.45 mi in 1956–57 to 1.4 mi in 1970.

To obtain similar results in oxidant concentration in 1970 in Pasadena, 74% removal of oxidant precursors is estimated to be required, as indicated graphically on Fig. 6. Visibility and eye irritation data were not available for this station.

Equation (2) may also be rearranged to solve for the estimated gasoline consumption for a given oxidant concentration. Solution indicates that the estimated gasoline consumption was 1.7 million gal per day when 0.15 ppm peak hourly oxidant concentration existed on 1% of the days at Los Angeles Station 1. This gasoline consumption corresponds approximately to that for year 1942.

All of the foregoing calculations are based on the assumption that precursors responsible for various air pollution manifestations are simultaneously reduced by equal percentages.

Plant damage, as a function of carbon monoxide concentration, was studied, but the simple correlation between these variables was too low to allow predicting their relation. Multiple regression analyses should enable a better determination of the important variables and their relative influence on plant damage.

General Applicability of Methods

The graphic and analytic methods for the California study have been applied to secondary pollutants or effects resulting from the interaction of primary pollutants. Those same methods may be applied in general to any pollutant for which the frequency distribution is known, e.g., suspended particulate concentration, which measurements are at the present time more generally available.

The value of b in Eqs. (2), (3), and (4) would obviously be set equal to 1, and Eq. 2 would become:

$$\% \text{ particulate removal} = 100\left[1 - \frac{\text{part.}}{\text{(source str.)(desired part. conc.)}}{\text{(est. future source str.)}(m_{yg})(s_{yg})^t}\right] \quad (5)$$

where m_{yg} = suspended particulate geometric mean concentration

s_{yg} = standard geometric deviation

t = number of standard deviations for the given frequency of occurrence, and present and estimated future source strength may be expressed in any consistent set of units.

Suppose for a given site that a frequency distribution of particulate values is available and that this distribution is represented by a geometric mean concentration of 136 μgm/m^3 and a standard geometric deviation of 1.8. Plan for 1970, assuming a 50% increase in particulate loading by that time. Assume that it is desired that filter samples not exceed 150 μg/m^3 on more than 10% of the days, corresponding to a value of $t = 1.28$. Substitution in Eq. (5) indicates a 65% overall reduction in source strength would be required. If it is desired that the 150 μg/m^3 level be exceeded on only 1% of the days, the required reduction would be 81%. Further, it is noted that the quantity $[(m_{yg})(s_{yg})^t]$ may be obtained graphically from the frequency distribution by reading the value of the pollutant level at the desired frequency of occurrence.

Appendix A

Given: Frequency distribution and regression data on CO, oxidant, eye irritation, and visibility at Los Angeles Station 1 and CO and oxidant at Pasadena Station 4.

Required: *1* Equation to predict degree of removal of oxidant precursor (as measured by carbon monoxide) necessary to obtain specified reduction in oxidant concentration, and

2 Predicted improvement in eye irritation and visibility for a given reduction of precursors (as measured by carbon monoxide).

Oxidant Removal—Los Angeles Station 1

A visual line of best fit for oxidant peak hourly concentrations is shown as Fig. 3. The median value (m_{yg}) and standard geometric deviation (s_{yg}) are as follows:

$$m_{yg} = 0.15 \text{ ppm oxidant}$$

$$s_{yg} = 1.63$$

The concentration for any given frequency of occurrence may be determined graphically or by determining t, the number of standard deviations for the given frequency of occurrence, from a table of t vs frequency, and substituting in the following equation expressing a straight line on a log probability plot (e.g., Fig. 3):

$$\text{conc.} = (m_{yg})(s_{yg})^t$$

For instance, at the 1% level, $t = 2.33$, and

$$\text{conc.} = (0.15)(1.63)^{2.33} = 0.47 \text{ ppm}$$

If it is desired to lower a given frequency concentration to a specified level, the percent removal necessary may be determined as follows:

$$\% \text{ oxidant removal} = 100\left(\frac{\text{original conc.-desired conc.}}{\text{original conc.}}\right)$$

$$= 100\left(1 - \frac{\text{desired conc.}}{\text{orig. conc.}}\right) \quad (6)$$

$$= 100\left(1 - \frac{\text{desired conc.}}{(m_{yg})\ (s_{yg})^t}\right) \quad (7)$$

Where t corresponds to the frequency of interest. In the example, for a concentration of oxidant 1% of the days equal to 0.15 ppm, the required percent removal is calculated as follows:

$$\% \text{ oxidant removal} = 100\left(1 - \frac{0.15}{0.47}\right) = 68\% \text{ removal}$$

Oxidant Precursor Removal—Los Angeles Station 1

Determine necessary removal of oxidant precursor, as measured by carbon monoxide, required to give 0.15 ppm oxidant on 1% of the days.

It is believed[1, 2] that the major source of oxidant precursor is the automobile. Based on this CO may be used as an index of oxidant precursor strength from this source.[3] Further, we may write, using Eq. 1, as follows:

$$\text{oxidant conc.} = a\ (\text{CO conc.})^b = c\ (\text{oxidant precursor})^b \quad (8)$$

If 68% removal of oxidant is desired, the necessary oxidant precursor removal (measured as CO) is calculated as follows:

$$\% \text{ oxidant precursor remov.} = 100\left[\frac{\text{orig. ox. prec.} - \text{de. ox. prec.}}{\text{orig. ox. prec.}}\right]$$

$$= 100\left[1 - \frac{\text{des. ox. prec.}}{\text{orig. ox. prec.}}\right]$$

$$= 100\left[1 - \left(\frac{\text{desired ox. conc.}}{\text{orig. ox. conc.}}\right)^{1/b}\right]$$

$$= 100\left[1 - \left(\frac{\text{desired ox. conc.}}{(m_{yg})\ (s_{yg})^t}\right)^{1/b}\right] \quad (9)$$

A regression analysis of oxidant as a function of CO indicates that when correlation is high, the value of b is approximately equal to 1.

$$= 100\left[1 - \left(\frac{0.15 \text{ ppm ox.}}{(0.15)\ (1.63)^{2.33}}\right)^{1/1}\right]$$

$$= 68\% \text{ removal}$$

Obviously the values for oxidant precursor removal and oxidant removal are the same, as the coefficient $b = 1$.

If it is desired to plan for a future year, say 1970, then the degree of treatment may be calculated as follows, based on a gasoline consumption of 8.8 million gal per day in 1970 as compared with 5.2 million gal per day in 1956–57.

$$\% \text{ oxidant precursor remov.} = \left\{1 - \left[\frac{(56\text{–}57 \text{ gasoline cons.})\ (\text{desired ox. conc.})}{\text{future yr. gasoline cons.}\ (m_{yg})(s_{yg})^t}\right]^{1/b}\right\} =$$

$$100\left\{1 - \left[\frac{(5.2 \text{ mgd})\ (0.15 \text{ ppm})}{(8.8 \text{ mgd})\ (0.15 \text{ ppm})\ (1.63)^{2.33}}\right]^{1/1}\right\} =$$

81% removal (10)

All of the foregoing calculations are based on the assumption that all oxidant precursors are simultaneously reduced by equal percentages.

Eye Irritation Improvement—Los Angeles Station 1

The degree of eye irritation relief that would be afforded by a 68% reduction of 1956–57 eye irritant precursor (measured as CO concentration) is calculated below.

As with oxidant, the regression line (Table I) for high correlation appears to be approximately:

$$\text{Eye Irritation} = a\,(\text{CO})^b, \text{ where } b = 1 \qquad (11)$$

If 68% removal of eye irritant precursors (measured as CO) were effectuated, then the future levels are predicted to be as follows, using the graphical solution of Fig. 4.

Degree of Irritation	—Given Irritation Equaled or Exceeded— % of Days 1956–57	% of Days 1956–57 After 68% Removal	No. of Days/Year After 68% Removal
Slight	40	4	15
Moderate	23	1	4
Severe	12	0.3	1

As with oxidant concentration, eye irritant data may be presented analytically. The equation previously developed for oxidant precursor (Eq. 5) may similarly be applied to irritant precursors as follows:

$$\%\text{ eye irritant precursor removal} = 100\left\{1 - \left[\frac{(\text{improved irrit. level})}{(m_{yo})\,(s_{yo})^t}\right]^{1/b}\right\} \qquad (12)$$

The frequency with which a given level is expected to occur may be determined by solving for t and obtaining frequency from a table of t vs frequency. Solving for t, we obtain:

$$t = \frac{\log\left[\dfrac{(\text{improved irritation level})}{(m_{yo})\left(1 - \dfrac{\%\text{ removal}}{100}\right)^b}\right]}{\log\,(s_{yo})} \qquad (13)$$

For a 68% reduction in the 1956–57 level of irritant precursors (corresponding to an 81% reduction in 1970 predicted levels), the predicted frequency of occurrence of slight eye irritation is:

$$t = \frac{\log\left[\dfrac{2}{1.7\left(1 - \dfrac{68}{100}\right)}\right]}{\log 2.06} = 1.85$$

From a table, t vs frequency, for $t = 1.85$, frequency = 3.3%, which checks the 3.6% determined graphically within the limits of plotting.

Also by rearranging Eq. (12) above, the eye irritant level experienced with a given frequency may be expressed as follows:

$$\text{Improved irrit. level} = (m_{yo})\,(s_{yo})^t\left[1 - \frac{\%\text{ precursor removal}}{100}\right]^b \qquad (14)$$

Visibility Improvement—Los Angeles Station 1

It is difficult to predict with any degree of certainty the increase in visibility that would accrue due to auto exhaust reduction. The correlation of visibility with CO is low (Table I). This is somewhat expected since many other types of particulate pollutants can also decrease visibility.

If auto exhaust visibility obscuring precursors and all other sources of visibility obscuring pollutants were reduced 68%, an analysis similar to that used previously may be made.

The equation previously derived for oxidant (Eq. 9) may similarly be applied to visibility. Note that the term s_{yo} appears in the numerator due to the inverse relationship of visibility reduction precursor.

$$\%\text{ visibility reduction precursor removal} = 100\left\{1 - \left[\frac{(\text{improved vis.})\,(s_{yo})^t}{m_{yo}}\right]^{1/b}\right\} \qquad (15)$$

Solving for improved visibility, we obtain

$$\text{Improved visibility} = \frac{m_{yo}\left[1 - \dfrac{\%\text{ reduction}}{100\%}\right]^b}{(s_{yo})^t} \qquad (16)$$

The minimum visibility (with relative humidity $\leq 50\%$) occurring on 1% of the days is 0.45 mi (Fig. 5). The value for b is estimated as -1, $m_{yo} = 3$ mi (Fig. 5), and $s_{yo} = 2.30$. Substituting in Eq. 16:

$$\text{Improved visibility} = \frac{(3\text{ mi})\left[1 - \dfrac{68\%\text{ reduction}}{100\%}\right]^{-1}}{2.30^{2.33}}$$

$$= \frac{(3\text{ mi})}{(6.96)\,(0.31)} = 1.4\text{ miles}$$

This checks the graphical solution.

Acknowledgments

Sincere appreciation is expressed to Messrs. Maga, Hass, and Perry of the California State Department of Public Health and to the staff of the Los Angeles County Air Pollution Control District for supplying the punched cards required for this study.

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2. A. J. Haagen-Smit and M. M. Fox, "Ozone Formation in Photochemical Oxidation of Organic Substances." *Industrial and Engineering Chemistry*, **48**, pp. 1484–87 (Sept. 1956).
3. Pre-meeting discussion material for "Technical Committee on Motor Vehicle Exhaust Standards," October 20, 1959, meeting at the California Department of Public Health Building in Berkeley, California.

CALENDAR

April 18–20	International Symposium on Chemical Reactions in the Lower and Upper Atmosphere, San Francisco, California.
June 4–9	Engineering Seminar, "Operating Principles and Industrial Applications of Electrical Precipitators," Pennsylvania State University, State College, Pa.
June 11–15	**54th Annual Meeting of APCA, Hotel Commodore, New York, New York.**

IN MEMORIAM

It is with deep regret that we announce the sudden death of Ellis E. Smauder, President of the American Incinerator Corporation, Detroit, Michigan. Serving as a Board Member from 1950–52, he was one of the founders of re-organized APCA, and at the time of his death he was serving as Chairman of the Incinerator Committee. His loss will be deeply felt by all who knew him.

CURRENT THINKING *on* METEOROLOGICAL INSTRUMENTATION *for Use in Air Pollution Problems*[*,†]

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HARRY MOSES, Meteorology Group Leader, Radiological Physics Division, Argonne National Laboratory, Lemont, Ill.,
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The need for meteorological information to help alleviate or minimize air pollution problems presents a challenge to the meteorologist and places a responsibility upon him. At a research planning seminar sponsored by the Robert A. Taft Sanitary Engineering Center in February 1958, deliberations by some two dozen meteorologists brought to light the need for clarification of many aspects of the techniques for making meteorological measurements pertaining to air pollution. The lack of standardization with respect to such features as the levels above the ground surface at which measurements should be made, the types of instruments to be used, the methods of data recording, the selection of averaging times, and the variation in the concept as to what needs to be measured made it clear that there was a need for a meeting of specialists in this field, both to discuss their differences and to provide a report containing information which may be used as a guide by those concerned with this problem.

Since the literature in the field of meteorological instrumentation related to air pollution is very sparse, the information contained in such a report would be of considerable value to anyone faced with the responsibility of recommending a program necessary to cope adequately with a particular air pollution problem.

A meeting was therefore called of the most active workers in the field of meteorological instrumentation with the objectives of: 1) discussing currently accepted practices, 2) exchanging views on the inadequacies of present day instrumentation, 3) arriving at an understanding of the problems encountered by the manufacturers of meteorological instrumentation, and 4) providing information on standards and procedures which could be used as a guide by those concerned with this problem.

It is hardly to be expected that an adequate set of standards and procedures could be set up from a one-day meeting. However, the accomplishments of such a gathering may well serve as a first step in this direction.

The meeting was called an Instrumentation Clinic and was under the sponsorship of the Air Pollution Committee of the American Meteorological Society.[1] It was held on March 24, 1959, at the Hotel Shoreland in Chicago, Illinois, as a part of the 175th National Meeting of the American Meteorological Society. The Clinic consisted of two sessions; one devoted to problems dealing with wind and turbulence measurements, and the other with those of temperature and stability measurements.

About 50 participants were invited and were given questionnaires prepared by the authors of this paper several weeks before the meeting to obtain a record of the current opinion on important aspects of meteorological instrumentation. This procedure also ensured the advantage of having the participants think about these problems prior to attending the meeting.

At each session there was only one invited speaker and he gave a broad outline of the topic under discussion. In addition, each session had a panel of three discussants to comment on the ideas presented in the main talk, to discuss portions of the questionnaire sent to the participants, and, of course, to inject pertinent ideas of their own.**

A written summary of the answers to the questionnaires was prepared by the session chairmen and distributed to the participants some time before the meeting to allow for rebuttal and comments on the open discussion.

Another feature of this meeting was an exhibit in which a number of instruments pertaining to the measurement of wind and temperature were shown. Each of the exhibitors was allowed a brief period to discuss features of his exhibit.

The entire proceedings were recorded on magnetic tape.

An analysis of the questionnaire replies prepared by the invited participants together with a review of the highlights of the discussions and a consensus of the opinions presented at the meeting as interpreted by the authors of this paper are presented below.

Temperature and Lapse Rate Measurements

In order to assess the current thinking on the value of temperature and lapse rate measurements in connection with

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* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

† Part of this work was done under the auspices of the Atomic Energy Commission.

** At the Wind and Turbulence Measurement Session: main address given by Robert A. McCormick, Weather Bureau Research Station, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati, O.: discussants—Raymond E. Kerr, Aerometric Research Incorporated, Santa Barbara Municipal Airport, Goleta, Calif.; Daniel A. Mazzarella, Friez Instrument Division, Bendix Aviation Corporation, Baltimore 4, Md.; and Benjamin Davidson, New York University, New York, N. Y. At the Temperature and Stability Measurement Session: main address given by Elmer Robinson, Bay Area Air Pollution Control District, 1480 Mission Street, San Francisco, Calif.: discussants—James Fuquay, Hanford Atomic Products Operation, General Electric Company, Richland, Wash.; R. C. Wanta, Booz-Allen Applied Research, Incorporated, Bethesda 14, Md.; and Harold V. Thompson, Beckman and Whitley, Inc., 973 San Carlos Avenue, San Carlos, Calif.

the air pollution problem and to find out what techniques are used, the following questionnaire was prepared and mailed to all participants. Twenty-four replies were received from individuals in the following categories: meteorological instrument manufacturers—1, industry—3, municipalities—3, Atomic Energy Commission—4, military—2, U. S. Weather Bureau—3, universities—6, and consulting firms—2.

In the following paragraphs the questions submitted are presented and the answers are summarized, It may be noted that the total number of answers do not add up to 24 since some of the answers did not lend themselves to tabulation.

A. Description of your stability measuring program. Are you currently making measurements of lapse rate? For what purpose are you making these measurements? Please describe in a few sentences the instrumentation you use to obtain measurements of atmospheric stability and how the data are analyzed for research or operational use.

Are you currently making measurements of lapse rate?

Answers:

Yes	12
No	3
Not currently	6

For what purpose are you making these measurements?

Answer: Many types of problems were mentioned which required data on the variation of temperature with height. Some of these were: community air pollution problems involving measurements of the times of onset and breakup of the inversion; the height of the inversion; the correlation of meteorological parameters with the diffusion of stack effluents; the establishment of an air pollution climatology; and basic research on atmospheric transfer processes.

Please describe in a few sentences the instrumentation you use to make measurements of atmospheric stability and how the data are analyzed for research and operational use.

Answers:

a	Supporting structure	
	1 tower	12
	2 balloon	4
	3 airplane or helicopter	2
b	Height range	
	1 greater than 500 ft	3
	2 250 to 490 ft	3
	3 100 to 240 ft	3
	4 less than 100 ft	2
c	Data recorded	
	1 actual temperature	5
	2 temperature differences	4
	3 both	5
d	Sensing elements	
	1 thermocouples	6
	2 resistance thermometers	8
	3 thermistors, aerometeorographs, ratiosondes (each)	1
e	Shielding and aspiration	
	1 shielded and aspirated	8
	2 Shielded but not aspirated	1
f	Method of recording	
	1 continuous record for each level	1
	2 Single pen recorder, switched in sequence to various levels	3
	3 multi pen recorder	3
	4 not listed	11
g	Use of automatic data analysis	
	1 continuous analysis and print out	2
	2 analysis by hand, punch cards later (by supposition remainder analyzed manually)	1

B. Accuracy requirements for obtaining atmospheric stability measurements. The cost of obtaining stability measurements might be substantially reduced by simplification of the equipment and of the analysis. How adequate for operational use would you consider an instrument that would classify and record air stability to five categories: very stable, stable, neutral, unstable, and very unstable? If such a scheme were adopted what temperature gradient boundary limits would you suggest for each category? At what height levels should the temperature difference measurements be made?

How adequate for operational use would you consider an instrument that would classify and record air stability into five categories: very stable, stable, neutral, unstable, and very unstable?

Answers:

consider adequate	12
consider inadequate	1
non-committal	1
suggested reducing the five categories to three	3

Table I

Stability Category (Values Are in °F/100 ft)[a]

Author[b]	Very Stable	Stable	Neutral	Unstable	Very Unstable
Danis	>1.0	1.0 to −0.1	−0.2 to −1.0	−1.1 to −2.0	<−2.0
Elder	>2.6	2.6 to 0.6	0.6 to −0.6	−0.6 to −2.0	<−2.0
Munn	>1.7	1.7 to 0.0	0.0 to −0.6	<−0.6	—
Pierrard	>1.4	1.4 to 0.5	0.5 to −0.5	−0.5 to −1.6	<−1.6

[a] Data were given in various units by the participants. These were all converted to °F/100 ft for ease of comparison.

[b] Rear Admiral A. L. Danis, College of Engineering, University of Florida, Gainesville, Fla.; Rex A. Elder, Hydraulic Operations and Tests Section, Tennessee Valley Authority, Norris, Tenn.; R. E. Munn, International Joint Commission, Air Pollution Laboratory, 108 McDougall Street, Windsor, Ont.; and John M. Pierrard, Armour Research Foundation, Illinois Institute of Technology, 10 West 35th Street, Chicago, Ill.

If such a scheme were adopted what temperature gradient boundary limits would you suggest for each category?

Answer: There was a surprisingly poor response to this question, but several specific answers were received. These answers were received from individuals working with towers ranging from 100 to 900 ft in height. Accordingly there was a marked divergence in the limits suggested. A sample of the answers are tabulated in Table I.

C. Value of atmospheric stability (lapse rate) measurements. The question is sometimes raised as to the need for lapse rate measurements in air pollution studies. In your opinion are atmospheric stability data necessary in determining the diffusive capacity of the air, or, is information on wind and/or other meteorological variables sufficient? Discuss briefly.

In your opinion are atmospheric stability data necessary in determining the diffusion capacity of the air, or, is information on wind and/or other meteorological variables sufficient?

Answer: As background material for this question it might be pointed out that the diffusion of an effluent depends almost entirely upon the air motions in the atmosphere into which the effluent is injected. For this reason, some meteorologists have stated that wind and turbulence measurements alone are all that are necessary in ascertaining the diffusive capacity of the air, lapse rate measurements being superfluous. Wind trace types[2,3] can be closely correlated with diffusion potential. Diffusion experiments with sulfur dioxide gas at O'Neill, Nebraska,[4] have shown a close correlation between atmospheric diffusion and the standard deviation of wind direction. The value of lapse rate observations seemed to be entirely secondary in studies of this type, hence the question.

The consensus (as indicated by the questionnaire, the formal paper, and the discussions at the Clinic) is that stability measurements should be continued at the present time. Although wind speed and direction observations at the height of a stack may correlate well with the diffusion of an effluent at a given time, most meteorologists desire lapse rate measurements when forecasting the diffusion potential for the next two or three hours. They also lean heavily on temperature observations when forecasting the height to which a heated plume will rise during periods of light winds and stable atmospheric conditions. Explanations for observed pollution at ground level can be made with far greater confidence if wind data are accompanied by lapse rate information. Furthermore, any of the recent equations for the rise of a heated plume or cloud require lapse rate information. For these reasons the consensus indicated a retention of temperature and lapse rate measurements.

The replies to the questionnaire on the "Value of Atmospheric Stability (Lapse Rate) Measurements," may be summarized as follows: consider them essential—10; consider them nonessential—1; essential sometimes, nonessential other times—10; noncommittal—3.

D. Points for discussion. What points would you like to have discussed at the atmospheric stability session of the instrumentation clinic?

Answers: Some of the topics on which discussion was requested are:

1 Characteristics of Instrumentation for Measuring Atmospheric Stability.
   a Time constants
   b Merits of thermistors, thermocouples, and resistance thermometers
   c Characteristics of radiation—ventilation shields
   d Data processing systems
   e Types of platforms
2 Philosophy of meteorological instrument manufacturing.
3 Statistical procedures involved in establishing climatological normals pertaining to air pollution.
4 The relationship between vertical temperature gradients and combinations of other meterological variables such as wind, solar radiation on a horizontal surface, and net radiation.
5 The creation of standards for stability measurements.
6 A discussion of fallout, rainout, and washout as related to stability.
7 The utility of local area broadcasts of baseline temperature, lapse rate, and wind data in major metropolitan areas for immediate technical application.

Consensus

The measurement of temperature to determine atmospheric stability requires a platform for mounting the thermal sensors. This platform may take the form of a tower, balloon, or heavier than air vehicle such as a helicopter, an airplane, or even a radio-controlled model airplane. On some occasions the stack itself or adjacent buildings have been used. The latter method is not recommended since it is difficult to avoid spurious temperature readings due to heating from the stack or building. In valley conditions, hillsides have been used as a platform. Comparison of the hillside measurements with tower, balloon, and airplane observations near the center of the valley (such as was made at Trail, B. C., and Richland, Washington) show that unrepresentative values of stability are obtained by this method. This is due to such effects as drainage winds or other local influences. Thus hillside temperature measurements are not recommended for stability measurements.

Balloons or aircraft do not permit continuous monitoring and are quite expensive if measurements are to be made over a long period of time. However, for some problems such as the community air pollution problem where information is required on the onset or breakup of the inversion, or the height of the inversion, balloons or aircraft provide the only means for obtaining the desired data. In most cases, however, towers provide the most practical support for temperature sensors.

Of course, in making stability measurements, the use of at least two levels for the temperature sensors are required. The uppermost level for the case of an air pollution problem associated with a particular plant should be somewhere above the effective height of the chimney or chimney complex. The recommended lower level is 20 to 30 ft above the ground. The latter recommendation stems from the fact that the temperature profile in the first few meters above ground is extremely nonlinear and is markedly influenced by the character of the immediate terrain. If sensors are mounted too close to the ground, extreme lapse rates are found which may lead to erroneous results when correlations between diffusion rates and stability are carried out.

Thermocouples, resistance thermometers, and thermistors are all used for measuring atmospheric stability. As seen by the answers to the questionnaire about an equal number use thermocouples and resistance thermometers. In general, the use of thermistors is not recommended because of their failure to maintain calibration for long periods of time. This is especially important for tower installations where, normally, months may intervene between calibrations.

For lapse rate measurements on conventional towers it is desirable that the measuring system be capable of measuring temperature to within 0.2°F. Slow response sensors such as those having a time constant of two to four minutes are recommended.

There are two methods normally used for making stability measurements. In the first, the ambient air temperature is measured at several levels and the temperature gradient is determined from the individual readings. The second method consists of measuring the temperature differences between the tops and bottoms of selected air layers. For example, if four levels are chosen let us say, levels A, B, C, and D, designated consecutively in ascending order, temperature differences between levels A and B, A and C, and A and D are recorded. Some prefer the arrangement of measuring the difference between D and C, D and B, and D and A. It is somewhat easier to tell at a glance the magnitude of the existing lapse rate when the lowest level (level A) is used as a reference. With either arrangement it is desirable that the ambient temperature be recorded simultaneously at some level so that the actual temperatures and temperature changes at the selected levels may be ascertained.

The recording equipment for stability measurements in which the ambient temperature is recorded generally requires a multiple range scale. With the conventional recorder having a chart width of 10 or 11 inches, and a temperature range of −20 to +120°F, the scale is too condensed to read temperatures to a required accuracy of 0.2°F.

For temperature difference measurements on a tower of about 150 ft, a range of −15° to +20°F will usually be satisfactory. However, the range selected must be a function of the tower height used. At the Argonne National Laboratory during extreme inversion conditions, a temperature difference of 20°F in the layer from 5.5 to 144 ft has been observed. At the Brookhaven National Laboratory an inversion of 34°F has been observed in the layer from 37.5 to 410 ft. Other installations have reported similarly extreme values. Thermal elements with a time constant of two to four minutes require radiation shields with artificial ventilation for accurate measurement. The most common radiation ventilation shield consists of two concentric cylinders with air drawn vertically upward through both passageways at a rate of 10 to 30 fps. The outer surface of the shield must be highly reflective to minimize the effect of solar radiation. Adequate ventilation is thus provided without causing significant aerodynamic heating effects. The dimensions of such a shield would depend on the size of the thermal element selected. Representative resistance thermometers using sensing elements measure one-fourth to three-quarter inches in diameter with the outer shield measuring one and one-half to two and one-half inches in diameter. Aeration of the thermal elements may be obtained by either of two methods: 1) individual blowers for each thermal element, or 2) a large single blower. Tower booms on which the thermal elements are mounted should be long enough to avoid spurious readings caused by air heating or cooling while passing through the tower.

For most work in measuring atmospheric stability a single recorder in which the data are recorded in sequence through a stepping switch or some similar arrangement is quite adequate. Cycling the temperature information 5 to 10 times per hour is usually sufficient.

For any given installation the use of automatic data processing equipment frequently becomes a question of eco-

nomics. Where relatively few measurements are made, the high initial investment for equipment to reduce the data automatically may not be profitable. At installations where large amounts of data are obtained, the use of automatic recording and analyzing equipment is, in most cases, justified.

Although only three of the replies to the questionnaire indicated that automatic processing equipment is being used, it is known to the authors that there are a number of installations in which the use of such equipment is contemplated in the near future. For example, at practically all of the AEC meteorological installations automatic data processing equipment is now in use or plans are underway to install such equipment.

Wind and Turbulence Measurements

A questionnaire on instrumentation for the measurement of various properties of the wind was distributed to the same individuals who received the temperature and lapse rate inquiry. Since the two questionnaires were prepared separately, they were not particularly similar in form or intent. The wind questionnaire was aimed at a more general coverage of the problem, and probably as a result of this, a smaller number of replies were received. Those who did respond, however, gave careful attention to the problems. The original questions and the responses are tabulated in the following paragraphs. In each case, the entire question is first repeated as it was given; then the specific points are repeated and summarized:

A. What aspects of the wind are important in terms of air pollution studies? We would all agree, I think, that a measurement of the horizontal wind direction and wind speed is a basic requirement. Do we also require an indication of the vertical wind? Many investigators have used variability of one or more of these components in their studies. Is variability an important parameter, and if you feel that it is, do you have any concrete suggestions concerning methods of measuring and using it?

Do we also require an indication of vertical wind?

Answers:

Yes	4
Required in certain studies, but not necessarily in all	9
Utilize horizontal fluctuations as an indicator of vertical	1
No reply	3

Is variability an important parameter?

Answers:

Yes	12
Sometimes	2
No reply	3

Do you have any concrete suggestions concerning methods of measuring and using it?

Answers:

Standard Deviation or variance	7
Mean value	1
Eye estimate from the original record	1
No reply	7

In relation to the first question, a number of important details are contained in the answers. Most individuals considered vertical wind a requirement in research studies, but not necessarily in individual plant or municipal problems. Many indicated that they considered lapse rate a more suitable measure of the vertical motion for the large-scale problems. In relation to the utilization and measurement of variability, seven respondents mentioned the importance of knowledge of the scale (both in time and distance) of the problem as an important feature in determining the need for variability measurements.

B. What sort of accuracy and responsiveness is needed for instruments of this type? Do we need to know the wind direction to 1°, 10°, 22½° accuracy? Similarly, what should the threshold wind measurement be, and what range of speeds needs to be covered? What response times should we be interested in for this type of work?

Do we need to know the wind direction to 1°, 10°, or 22½° accuracy?

Answers:

22½°	5
10°	4
1°	3
No reply	5

In responding to this question, many again stressed knowledge of the problem in order to determine the accuracy required. In research studies, for example, few would be satisfied with accuracies of 10°, but would rather require 1° or 2°.

What should the threshold wind measurement be?

Answers:

½ to 1 mph	9
No specific reply	8

What range of wind speeds need to be covered?

Answers:

0 to 15 mph	1
0 to 30 mph	2
0 to 60 mph	5
0 to 100 mph	1
No reply or multiple scales	8

What response times should we be interested in for this type of work?

This portion of the question did not usually receive a specific answer. Many of the participants suggested that they would be quite satisfied with slow response or artificially lagged records for the long period data, virtually but all of them stressed that there was a need for a fast response and a high order of accuracy where variability was being measured.

C. Perhaps the most important question is the final form in which we require the data. While I think several alternative types of recording might be a desirable feature, it seems to me that the paper and ink record in its usual form is often not desirable. Should we have some summary of the values over time periods recorded directly and automatically? What should these be?

Should we have some summary of the values over time periods recorded directly and automatically?

Answers:

Punched cards or tape as a preferred record	11
Some summarized value, but no definition of its type	3
Pen and ink	1
No reply	2

It is of some importance to note that many of the individuals felt that they would prefer to retain the capability of the instruments for pen and ink recording, even though they did not expect to utilize it routinely. The argument here was that there are certain aspects of the pen and ink record, such as the ability to read the material immediately, which cannot be obtained any other way.

What time periods should these be?

Answers:

½ to 1 hour	6
Variable depending on the problem	2
A few seconds to a few minutes	1
No specific reply	8

D. Maintenance and durability become quite important in many surveys where the number of instruments used is large. How much emphasis should be placed on durability and simplicity of repair? What do you consider a reasonable period between routine maintenance checks? Are existing instruments standing up well under their conditions of use? I, for one, have heard complaints about corrosion in contaminated municipal atmospheres. How general is this problem?

How much emphasis should be placed on durability and simplicity of repair?

Answers:

Of first importance	6
Of equal importance with other aspects	6
No specific reply	5

What do you consider a reasonable period between routine maintenance checks?

Answers:

Weekly	2
Bi-weekly	1
Quarterly	3
Annually	1
No specific reply	10

Clearly this portion of the question was poorly worded, because some of the people were thinking of inspection, chart changes, and other simple tasks, while others obviously were discussing major maintenance.

Are existing instruments standing up well under their conditions of use? I, for one, have heard complaints about corrosion in contaminated municipal atmospheres. How general is this problem?

This question received specific answers from rather few of the individuals, but it is worth noting the type of failures which were brought to the attention of the Clinic.

Answers:

Corrosion of aluminum in atmospheres containing sea salt	2
Corrosion of hot-wire anemometers by sea salt and other atmospheric pollutants	2
Susceptibility to lightning damage	2
Failure of plastics in severe northern climates	1
No knowledge of corrosion	2

E. While the above questions are fundamental in the sense that we need to reach some measure of agreement on them before anything else can be done, I do not feel that we should ignore the problem of cost. No specific question can be directed to you because of your variety of interests, but we would like to have you retain this viewpoint in regard to the session. In particular, it would probably be very helpful to have a more firm idea of the general level of reduction in cost which might be achieved by simplification and standardization, and to know what total expenditures are considered reasonable by municipal and industrial organizations.

This question, as indicated in the text itself, did not necessarily require a specific answer. It was introduced to elicit a response from the instrument manufacturers in terms of the ways in which we might achieve cost savings. Such a response was received at the general session, and is covered in a later section.

Half of the participants did have specific views about cost. Most of them felt that, for general use in air pollution surveys, a total instrument including transmitters and recorder should cost approximately $500 to $1000. A number recognized in their discussions that a punch card or paper tape machine could be expected to summarize the inputs from many instruments, and that there would be no objection to a fairly high cost for this unit if the individual transmitters were not too expensive.

Consensus

From the foregoing replies, together with the additional verbal comments received during the course of the clinic itself, it is possible to summarize the session on the wind and turbulence measurements.

Tower-based wind speed and direction measurements are essential in virtually all air pollution surveys, and most users consider an added quantity reflecting the fluctuations or variability of the wind as a desirable parameter. It was not possible at this session to achieve full agreement as to what this measurement should be, but it seemed apparent that standard deviation would be considered a valuable quantity by most. A measure of the vertical wind is believed necessary in some studies, particularly the more detailed individual plant surveys, but it appears to be of limited value in defining the broad municipal type of problem. In the latter case, vertical temperature structure is considered by many to be a better indicator of vertical motion.

For the most part, mean values of the wind speed and wind direction and the standard deviation of wind direction would be acceptable if obtained over one-half to one hour periods, and very few of the participants would object to a directional accuracy no better than 10° for this type of measurement. However, most participants have concluded that they need a wind speed instrument which will start at one-half to one mph, presumably because of the importance of light winds. The range of wind speed desired is quite variable depending on the problems of interest.

While mean values of rather rough accuracy were considered acceptable, it was pointed out that a fairly precise instrument was needed to sense variability in wind speed and direction.

Most of the participants believe that the existing wind instrumentation is adequate in terms of durability and resistance to corrosion. However, they did point out that durability was perhaps the most important characteristic of the instruments, and that long periods between calibration and major maintenance are considered desirable. A significant number of the participants would probably accept ninety days as a suitable period between minor checks and one year for a major maintenance schedule. Practically all participants are dissatisfied with the fact that existing wind instrumentation seldom is available ready for direct coupling into a punched card, paper tape, or other summarized data form. The familiar pen and ink record has lost favor almost completely, except as a visual check on the performance of the equipment. Most desirable would be appropriate transmitting instruments which could be coupled to one or another "black box" and thence into a final output of some generally acceptable automatic form.

While one finds the expected desire that cost be reduced, there was no consistent argument that current costs are particularly excessive. It is believed, however, that standardization and simplification could produce suitable equipment in the $500 to $1000 class.

Comments on Discussions

It was recognized early in the discussion and stressed by Robert A. McCormick in one of the main addresses, that there are really three categories of endeavor pertaining to the meteorological aspects of the air pollution problem: 1) the acquisition of meteorological data for climatological use, 2) day-to-day operations, and 3) research. The requirements for accuracy, sensitivity, and cost usually vary in this order. However, a major portion of the discussion and thought was devoted to the meteorological measurements which may be applied to daily routine operations.

In addition to the comments dealing with instrument characteristics and features of measuring techniques, the discussions by participants centered about, 1) problems of instrument manufacturing, 2) techniques of measurement, and 3) other meteorological problems requiring attention as indicated below.

Problems of Instrument Manufacturing

The lack of recommendations by a responsible group concerning instrumentation standards was a cause for concern among the representatives of the instrument manufacturers. Among the participants were Daniel A. Mazzarella of the Friez Instrument Division, Bendix Aviation Corp., and Harold V. Thompson of the Beckman and Whitley, Inc. If instruments are to be mass produced and thus provide a cost saving to the consumer, standardization is of utmost importance. A further monetary saving could be realized by the intelligent specification of instrument characteristics guided by instrumentation standards. For example, purchasers of equipment for daily routine operations often overspecify the wind speed threshold as one-half mph, when one mph would be adequate. Another feature of anemometers which may well be standardized are wind speed ranges. Requests for anemometers with ranges of 0 to 60 mph, 0 to 100 mph, or 0 to 125 mph are often received. In many of these cases the same range would be quite satisfactory. The resolution of wind direction to 8, 16, or 36 points is another characteristic which may be standardized.

Manufacturers decried the lack of flexibility on the part of some users for refusing to change over from one type of measurement to another for fear of losing continuity in cases where this

would make little difference. For example, when direction measurement has been made to 8 points of the compass, the buyer would refuse to buy an instrument measuring direction to 16 points. A statement by a responsible group on changeovers of this type would be desirable.

As an aid to drawing up recommendations for standardizing practices, it was pointed out that a survey of current practices in measurement techniques would be of great help. Each of the manufacturers present at the meeting has made rather limited surveys for their use, but a more extensive survey was recommended.

A plea was made for co-operative buying on the part of groups having similar requirements. Universities, municipalities, or various branches of a government department could profitably participate in such an arrangement.

Participants were urged to purchase equipment by competitive bidding from reliable manufacturers, and, wherever possible, through the use of a set of specifications.

New Techniques of Measurement

One of the most promising schemes for obtaining information on air trajectories was described by Donald H. Pack of the U. S. Weather Bureau. This technique consists of sending aloft constant level balloons called "tetroons," since they are tetrahedrons in shape. The balloons are made of aluminized mylar and are filled with helium. The tetroons may be tracked by radar to distances of tens of miles and heights approaching 10,000 ft. Preliminary tests are very encouraging. The use of radar to locate the heights and duration of inversions was discussed, but apparently such work needs to be done on this problem before practical results are forthcoming.

The use of radio-controlled model aircraft to carry aloft thermal sensors for the purpose of providing information on inversions and stability was described by Robert A. McCormick. Heights of several thousand feet may be reached without the need for lead wires. This eliminates the danger arising from the lead wire falling on high-tension power lines. R. C. Wanta described an instrument for measuring temperature on the tower using a battery-operated transistorized oscillator, whose frequency varies with temperature. Since the power requirements of transistorized equipment are small, it would be possible to operate it for a number of months before a battery change would become necessary. With this arrangement one can avoid the expense of installing lead wire from the tower to the building where the recorders are located.

The use of radon as a means for determining the behavior of an effluent from a large area source was discussed. An insufficient amount of work has been carried out for the efficient use of this technique as a routine air pollution indicator. However, what has been done is very promising.

Dr. C. W. Thornthwaite described a simple anemometer giving the horizontal wind direction to eight points with a starting speed of 0.2 mph. Information on vertical wind was also provided. Counters and photographic equipment are used for the recording.

Other Problems Requiring Attention

It was pointed out that the direction of travel indicated by an anemometer, especially during light winds, is inadequate for determining the path an effluent will take in the first few miles. Thus intolerable errors arise when anemometers are used for this purpose. Emphasis was placed on the need for trajectory studies in connection with site-location considerations for industrial establishments which have air pollution problems. Work on improved techniques for determining air trajectories was strongly recommended.

The dearth of available data on atmospheric stability was disappointing. It was suggested that measurements of stability and wind profiles in the vicinity of large metropolitan areas be made continuously on a routine basis. A reference station of this type would not necessarily supplant similar observations made near an industrial establishment which had an air pollution problem, but would be very useful for comparison. If a network of reference stations were established, meteorological consultants would no longer find themselves in the embarrassing position of having to estimate data on stability and wind profiles. Radiosonde data may serve to a limited extent in providing stability data in the lower layers of the atmosphere, but such data are not only too crude but also too few and far between both in time and space.

It is well known that diurnal and annual patterns of stability in the lower atmospheric layers vary with latitude and also from place to place in the same latitude band. It was suggested that a national climatic summary of stability data would be very useful. A network such as suggested above would, of course, be necessary for an adequate summary. However, information on stability obtained from radiosonde data may be used at first.

Suggestions were made that work be conducted to find out to what extent data on solar radiation on a horizontal surface or net radiation flux may serve as indicators of the dispersive capacity of the atmosphere. Of course, these meteorological variables are correlated with both stability and wind speed profiles. A saving in measurement costs might be effected if these variables can, at least to a first approximation, replace stability and wind profile data.

Conclusions

In spite of the differences in measuring equipment and measuring techniques, a rather large area of agreement was evident both from the discussions and answers to the questionnaires. It was commonly agreed that wind speed, wind direction, and stability are the meteorological elements most pertinent to the air pollution problem and that wind direction and stability need not be measured with great precision. Wind direction may be measured to eight or sixteen points and stability to five categories. Because of the rather high correlation recently found between atmospheric diffusion and wind direction variability, it was felt that the latter parameter should also be measured but the exact statistical form was left open.

Since continuous measurements result in a vast accumulation of data, the need for stability and wind data processing equipment at reduced cost was recognized.

It was generally accepted that the establishment of a set of recommendations for use as a guide in obtaining meteorological measurements was most desirable. The numerous requests for information on measuring techniques received both by meteorologists working in this area and by meteorological instrument manufacturers together with descriptions in the open literature of the difficulties arising from air pollution emphasize the need for such recommendations.

The beginning made by the Instrumentation Clinic in setting up a guide for meteorological measurements pertinent to air pollution should be extended. The authors believe that a convenient means of doing this could be found in the establishment of a project at one of the Universities having a staff both qualified and interested in carrying out the task. It is further recommended that such a project be sponsored by the American Meteorological Society or the Air Pollution Control Association and financed by one of the appropriate agencies.

Benefits arising from an effective set of recommendations would result in: 1) more useful meteorological information for decision making, 2) reduction in instrumentation costs due to standardization, 3) valid comparison of meteorological data obtained at different locations, and 4) saving considerable time by meteorologists and engineers in designing installations for obtaining meteorological data.

(*Continued on p. 96*)

SUCCESSFUL CLEANING *of Open-Hearth* EXHAUST GAS *With a High-Energy* VENTURI SCRUBBER*

C. A. BISHOP, W. W. CAMPBELL, D. L. HUNTER, and **M. W. LIGHTNER,**
Applied Research, U. S. Steel Corporation

During the past decade, the United States Steel Corporation has conducted extensive research directed toward improving the performance and decreasing the cost of equipment for cleaning open-hearth exhaust gas. Some of you may recall that at the 48th meeting of this association at Detroit in 1955, a report was made of the results obtained in a pilot-plant investigation of the optimum size and operating conditions for electrostatic cleaning of open-hearth gas. The investigation showed that there was little likelihood of reducing the required size or cost of electrostatic-precipitator systems. The investigation also showed that although the several full-scale systems which had been installed by 1955 were adequate at that time, the high level of cleaning performance that would probably be required in the future could not be attained with most of these systems. The reliability and performance of precipitators have been considerably improved in recent years by the advent of electron-tube-type rectifiers to replace the old mechanical rectifier for the conversion of the low-voltage alternating current to high-voltage direct current, and by new automatic voltage-regulating devices for maintaining the optimum sparking voltage between the discharge and collecting electrodes. But a more economical and more reliable device for cleaning open-hearth exhaust gas is still avidly sought.

Consequently, attention was turned once again to Pease-Anthony venturi-scrubber systems. A pilot-plant investigation of this type of system in 1955 had shown that the venturi scrubber could satisfactorily clean open-hearth gas. A preliminary cost estimate indicated that despite the need for corrosion-resistant materials of construction, the capital cost of the venturi-scrubber system for cleaning open-hearth gas would be somewhat less than that for a precipitator, and considerably less where a waste-heat boiler would be required for temperature conditioning of the gas for a precipitator. However, the savings in capital investment would be rapidly offset by the higher operating costs of a venturi-scrubber system. The higher operating cost is primarily due to the power expended in pulling the gas to the scrubber at a pressure drop of about 30 inches of water. However, because of subsequent improvements in both the design and the operation of the Pease-Anthony venturi-scrubber system, in many cases scrubbers now appear to be more favorable than precipitators for cleaning open-hearth exhaust gas. This is especially true for shops where waste-heat boilers would be required. Also, the lower capital investment for venturi scrubbers would offset higher operating costs in shops that are in operation only when there is a peak demand for steel or that will be dismantled in a few years.

Although it was recognized that the power requirements of the venturi scrubber would be high, the pilot-plant work was sufficiently encouraging to suggest a full-scale evaluation of the prior findings. Accordingly, a venturi-scrubber system was installed in 1959 at Edgar Thomson for cleaning the exhaust gas from No. 4 open-hearth furnace. Applied Research Laboratory personnel co-operated with plant personnel in operating and evaluating the performance of this venturi-scrubber system. The results are presented in this paper.

Description of Open-Hearth Process

Before a review of the results obtained with the scrubber, a brief survey

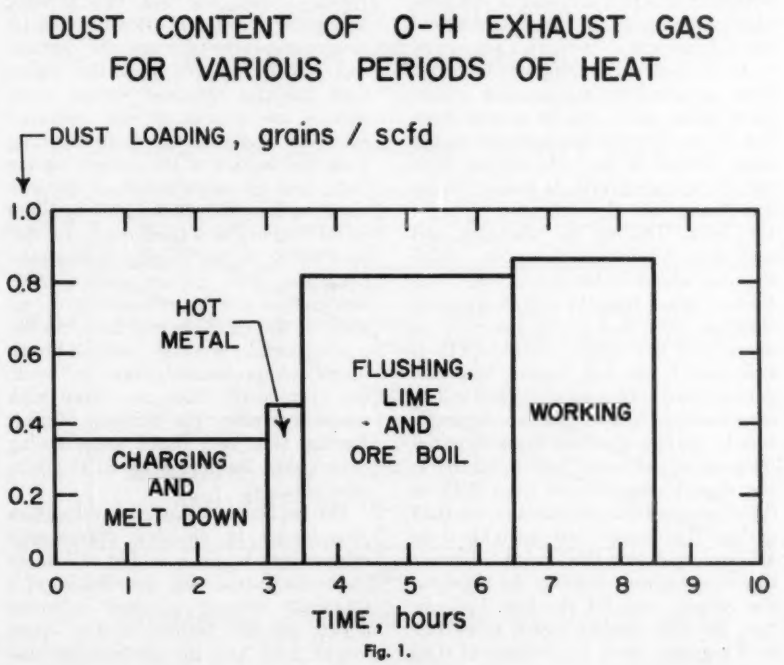

Fig. 1.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

of the open-hearth process may be helpful in understanding the difficulties encountered in cleaning the gas from this type of metallurgical operation.

The open-hearth operation is a batch melting process performed in a covered, rectangular furnace with a hearth shaped like a shallow, rectangular dish. The furnace is charged with pig iron and hot metal from the blast furnace, together with scrap, iron ore, and limestone. The charge is melted at temperatures as high as 3000°F by the combustion of a fuel such as oil, natural gas, tar, or coke-oven gas, with an excess of preheated air. The hearth is called "open" because the contained charge is open to the sweep of the hot combustion gases across its surface. The high temperatures, coupled with oxidizing ore and the excess of air, oxidize part of the carbon and other elements that are to be removed from the iron. The limestone fluxes the impurities and holds them in the form of a slag layer. A single batch of steel, which may weigh as much as 600 tons and may require from seven to 12 hours to process, is referred to as a "heat."

The particulate matter carried by the open-hearth exhaust gas presumably results from the pickup of fines from the charge material, the agitation and chemical reactions of the molten bath, and the combustion of the fuel. Because the reactions occurring in the bath vary from one period of the open-hearth heat to the next, the exhaust gas likewise varies considerably in appearance, composition, and dust loading during the course of a heat. Normal variability in raw materials and in furnace operation, as well as changes in operating practice, also causes considerable variation in the characteristics of the exhaust gas.

An idea of the nonuniform demands that open-hearth gas-cleaning equipment must meet can be gained from Fig. 1, which shows the variation in the dust content of the exhaust gas from the No. 4 open hearth at Edgar Thomson Works for the different parts of the heat. During the charging and melt-down period of the heat, which requires about three hours, the dust loading varied from 0.1 to 0.58 grain per standard cubic foot of dry gas, with an average of 0.35 grain. (Unless otherwise stated, the dust loading in grains per standard cubic foot of dry gas will be expressed as "grains" in this presentation.) During the half hour required for pouring hot metal into the furnace, the dust loading varied from 0.24 to 0.66 grain, with an average of 0.45 grain. No oxygen was introduced to the furnace during this period. During the three hours required for flushing the furnace and for the lime and ore boil, the dust loading varied from 0.14 to 1.6 grains, with an average of 0.82 grain. Finally, during the working or refining period of the heat, which requires about two hours, the dust content of the gas varied from 0.51 to 1.2 grains, with an average of 0.87 grain. During the last two periods, high-purity oxygen is often injected by means of lances through the furnace roof. It is believed that the higher dust loadings obtained during these periods are caused by the increased agitation of the molten bath resulting from the impact of the oxygen on the bath, and by vaporization of the iron resulting from the much higher localized metal temperatures (perhaps up to 5000 to 6000°F) in the vicinity of the lance tip. The iron vapors subsequently condense in the lower-temperature regions of the checkers and flues, readily oxidize, and produce reddish-brown fumes. Approximately once a week, the open-hearth flues are blown with steam to remove the build-up of soot. During this very brief soot-blowing period, dust loadings of up to 15 grains were obtained.

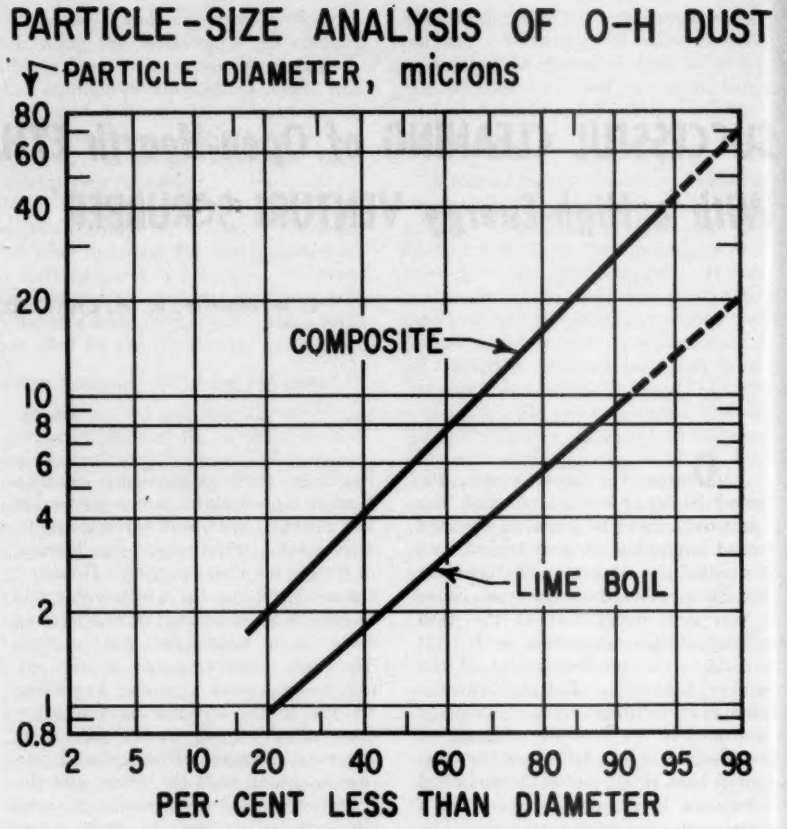

Fig. 2.

Further evidence of the difficulties encountered in cleaning open-hearth exhaust gas is given in Fig. 2, which shows the particle-size distribution of a composite sample of dust collected during all the periods of the open-hearth heat and the particle-size distribution of a sample collected during the lime boil. The dust was very finely divided, and the size distribution varied considerably during the heat. Only about 46% of the composite sample was less than five microns, whereas about 77% of the sample collected during the lime boil was less than five microns.

Thus, because of the considerable variability in the properties of the stack gases and dust from the open-hearth process, it is often difficult to obtain the desired high level of performance from the gas-cleaning equipment.

Description of Venturi-Scrubber System at Edgar Thomson Works

The high-energy Pease-Anthony wet-scrubber system installed on one of the 200-ton open-hearth furnaces at Edgar Thomson Works consists essentially of a gas restriction and a water-spray system at the restriction. The turbulence created by the gas passing through the restriction atomizes the water and permits intimate contact between the water droplets and the solid dust particles in the gas stream. The wetted particles are then removed from the gas stream as the gas passes into an inertial-type entrainment separator. In a venturi scrubber the restriction consists

of a throat section connecting converging and diverging duct sections.

A schematic layout of the scrubber system at Edgar Thomson is shown in Fig. 3. In operation, the gas (about 40,000 scfm) is taken from the underground waste-gas flue from the No. 4 furnace and is passed through the venturi scrubber and the entrainment separator section before being discharged by means of an induced-draft fan to the atmosphere through a new exhaust stack located on top of the entrainment separator. Because there is no 60-cycle power available at the open-hearth shop, the fan is driven by a steam turbine. The dirty water is removed from the separator and is recycled through a pump to the scrubber throat. To prevent plugging of the venturi spray nozzles and fouling of the recycle pump with suspended solids, three to five percent of this dirty water is bled from the system and discharged into an existing sump, where the bulk of the solids settle out before the water is discharged to the plant sewer system. Make-up water to replace the water lost by evaporation and the water bled to the sewer system is introduced into the entrainment separator; it is controlled automatically by a float-control system.

Because corrosion would present a serious problem in a wet system, several different materials were used in fabricating the various components of this system so that their relative corrosion resistance could be determined. The entire venturi scrubber, the exhaust fan, the duct work connecting the water separator and the fan, the duct work connecting the fan and the exhaust stack, and the internal spin-vane elements of the water separator were fabricated from Type 316 stainless steel. The inner wall of the cyclonic-type water separator was lined with lead, then built up with two inches of epoxy resin, and finally backed up with acid-resistant bricks. The exhaust stack was internally lined with a shop-baked phenolic coating. In addition, test panels were exposed to the dirty water in the bottom of the entrainment separator and to the cleaned gas at the base of the exhaust stack. The materials tested were carbon steel, USS Cor-Ten, Type 410 stainless steel, Type 316 stainless steel, Carpenter-20, USS Corex, Cat-a-lac, and Tarset. The last two materials were coatings applied to carbon-steel panels; Tarset is an epoxy resin, a coal-tar product; and Cat-a-lac is a chemically cured epoxy resin.

Evaluation of the System

Scrubber Cleaning Performance

The first objective was to determine the cleaning performance of the system for various operating conditions. The effect of the pressure drop on scrubber cleaning performance is shown in Fig. 4. Note that the cleaned-gas dust loading varied inversely with pressure drop. The dust loadings obtained during the flushing, the lime and ore boil, and the working period (those periods when oxygen was normally introduced into the furnace) were essentially the same for a given pressure drop. Similarly, the loading for a given pressure drop was essentially the same for the charging, the melt-down, and the hot-metal periods (the nonoxygen periods of the heat). However, the cleaned-gas dust loading for a given pressure drop was slightly higher during the periods when oxygen was introduced to the furnace. From these curves, for different pressure drops and for both the oxygen and nonoxygen periods of the heat, a selection can be made of average cleaned-gas dust loadings that can be used to calculate scrubber cleaning efficiencies.

The effect of scrubber pressure drop on cleaning efficiency and outlet dust

VENTURI SCRUBBER FOR OPEN HEARTH

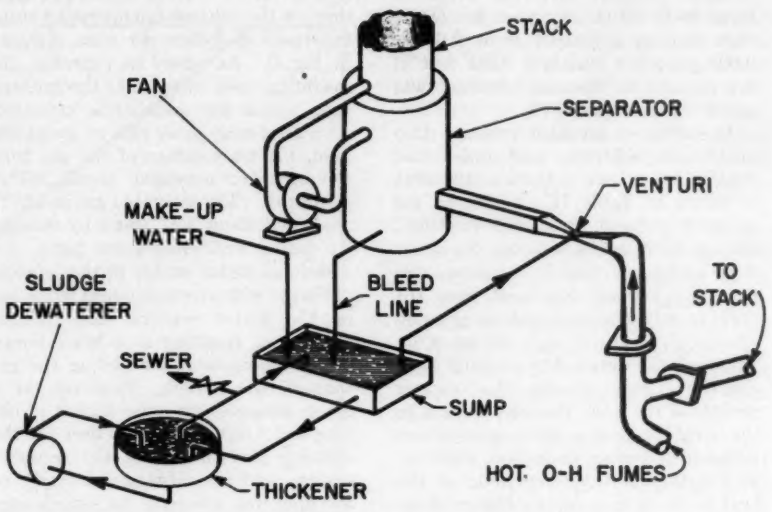

Fig. 3.

PRESSURE DROP VS SCRUBBER PERFORMANCE

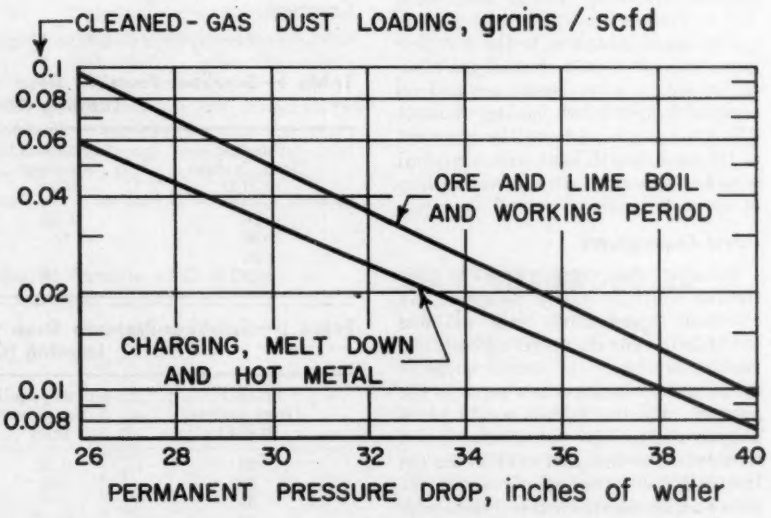

Fig. 4.

loading for nonoxygen periods of the heat is presented in Table I. As the scrubber pressure drop was increased from 26 to 40 in. of water, the outlet dust loading decreased from 0.06 to 0.008 grain per standard cubic foot of dry gas and the cleaning efficiency was improved from 86 to 98%.

The effect of scrubber pressure drop on cleaning efficiency and outlet dust loading for oxygen periods of the heat is shown in Table II. Again, as the scrubber pressure drop was increased from 26 to 40 inches of water, the outlet dust loading decreased; however, this time the loading decreased from 0.1 grain to only 0.01 grain and the cleaning efficiency increased from 89 to 99%. Although the outlet dust loadings were slightly higher during the oxygen periods of the heat, the inlet loading to the scrubber during these periods was sufficiently higher than that obtained during the nonoxygen periods of the heat to result in a slightly higher cleaning efficiency during the oxygen periods. During the soot blow, when the inlet loading can be as high as 15 grains, an outlet dust loading of 0.06 grain was obtained with a scrubber pressure drop of 36 in. of water; and the resulting cleaning efficiency was 99.6%. The extremely high efficiency obtained during the soot blow was due to the increased concentration in the gas stream of large-diameter particles, which are easily wetted in the venturi throat and readily removed in the entrainment separator.

Although there is a large cloud of steam condensing on contact with the ambient air, there is seldom any discoloration of the effluent from the scrubber when the scrubber is operating at pressure drops of 30 in. of water or higher, and with a scrubbing water rate of 500 gpm. Means for reducing this steam plume and the effect on scrubber operating costs of reducing it will be discussed later.

The results obtained in the test program indicate that a cleaned-gas effluent of satisfactory appearance and an acceptable outlet dust loading of about 0.05 grain can be obtained for any part of the open-hearth heat with a venturi scrubber operating at a pressure drop of about 30 inches of water.

Power Requirements

Because the steam flow to the turbine could be easily measured, an excellent opportunity was afforded to obtain data on the operating costs of a venturi scrubber at various pressure drops and scrubbing-water rates to the venturi. Electric motors would probably be used to drive the exhaust fans if scrubbers were installed to clean the gas from all the furnaces; therefore, the power requirements for this system were converted to brake horsepower and the costs were calculated with the use of a power cost of $1 per hundred horsepower hours. The effect of venturi-pressure drop on the exhaust-fan operating costs, expressed in dollars per year, is shown in Fig. 5. As would be expected, the operating costs increase as the pressure drop across the scrubber is increased. At a scrubbing-water rate of about 500 gpm, the temperature of the gas from the scrubber averaged about 165°F, saturated. The saturated gas at 165°F contained about 35% water by volume. At higher scrubbing-water rates, the additional water causes further cooling of the gas with a corresponding reduction in the water content and volume of the gas, resulting in a lower horsepower requirement for pulling the gas through the system. However, at a given pressure drop the higher scrubbing-water rates had no effect on the cleaning performance of the scrubber system, and a scrubbing-water rate of 500 gpm was adequate for satisfactory scrubber cleaning performance. The additional water for cooling could therefore be better applied in a tower specifically designed for that purpose. A reduction in the temperature of the gases from 165°F to 110°F, saturated, in a cooling tower would further reduce the fan operating costs shown in Fig. 5 by approximately 30%. This reduction in operating costs would more than offset the additional operating costs for pumping the cooling water to the cooling tower. However, on an entire-shop basis, the capital investment cost of a scrubber system would be higher if the gas were cooled, because of the need for a new river pumping station, a new water line to the open-hearth shop, and new sewer facilities. The cooling of the gases to 110°F, saturated, would also significantly reduce the steam plume in the exhaust from the scrubber system.

Corrosion

The scrubber system at Edgar Thomson has not been in service long enough to permit a conclusive evaluation of the materials of construction. At present it can be stated, however, that carbon steel, USS Cor-Ten, and Type 410 stainless steel are not satisfactory for this type of service. In fact, the carbon-steel specimens exposed to both the gaseous and the liquid phase completely disappeared after about one week of service. To date, Type 316 stainless steel, Carpenter-20, and USS Corex appear to be satisfactory as a material of construction for all parts of the system except the throat of the scrubber and the duct section connecting the throat and the entrainment separator. Severe pitting, probably caused by both erosion and corrosion, has been observed in these areas. However, this problem can probably be eliminated by lining these sections with silicon-carbide bricks or with lumnite cement using a heydite aggregate. The specimens coated with Cat-a-lac were severely attacked in both the liquid and the gaseous phase of the operation. One of the Tarset specimens showed no signs of attack, but the other was attacked; it is suspected that there was a small pinhole in the coating of the latter, which exposed the metal surface to the corrosive conditions. This points out the fact that if coatings are to be used for this purpose, considerable care must be taken in the application of the coating to the metal surface. An analysis of slurry samples taken during the course of the test program revealed an average pH of three for both the water from the separator and the liquid condensate in the base of the exhaust stack.

Slurry Handling and Treatment

Immediately after the venturi-scrubber system at Edgar Thomson was put into operation, considerable difficulty was experienced with plugging of the recycle scrubbing-water pump and of the

Table I—Scrubber-Pressure Drop vs Cleaning Efficiency and Outlet Dust Loading (Nonoxygen Periods)

Pressure Drop, Inches of H_2O	—Dust Loading, Grains per Scfd— Scrubber Inlet	Scrubber Outlet	Cleaning Efficiency, %
26	0.35	0.06	86
30	to	0.03	92
35		0.01	96
40	0.45	0.008	98

Table II—Scrubber-Pressure Drop vs Cleaning Efficiency and Outlet Dust Loading (Oxygen Periods)

Pressure Drop, Inches of H_2O	—Dust Loading, Grains per Scfd— Scrubber Inlet	Scrubber Outlet	Cleaning Efficiency, %
26	0.82	0.10	89
30	to	0.05	94
35		0.02	97
40	0.87	0.01	99

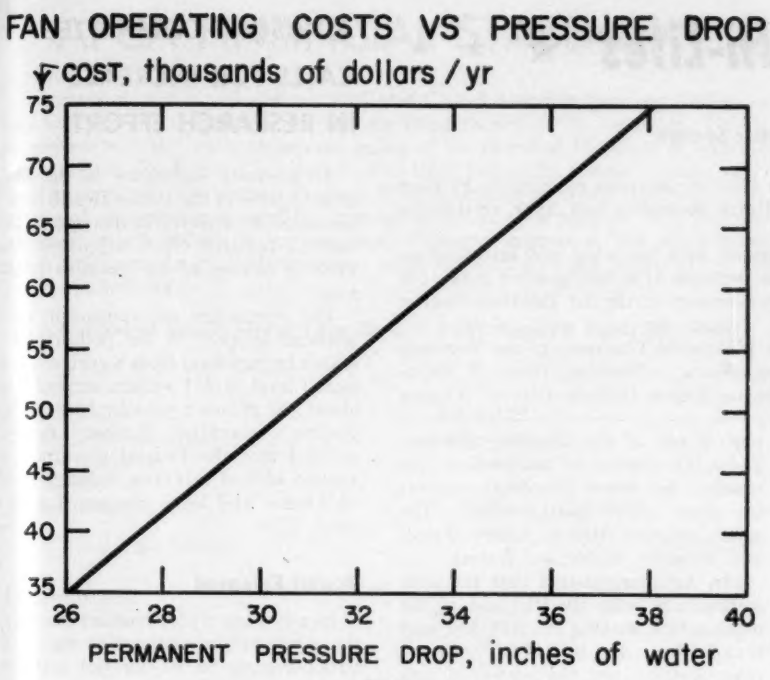

Fig. 5.

spray nozzles at the venturi throat by the solid material in the recycle scrubbing water, especially during those periods when the flues were being blown with steam. However, this problem has been overcome by reducing the number of spray nozzles in the venturi throat, by enlarging the diameter of the openings in the venturi throat, and by reaming out the openings more often. After this initial plugging condition was eliminated, satisfactory operation of the recycle-water system could be obtained if about 25 gal of slurry per minute were bled to the settling basin. The solids content of this bleed slurry averaged about 1½% by weight. During the soot blow, the solids content of the slurry was as high as 27% by weight; most of the plugging problems occurred immediately after a soot blow. However, plugging should not present a serious operating problem with a full-shop scrubber system, because all the scrubber water would be delivered to a primary sump where the larger solid particles could settle out before the water was recycled to the scrubber. Laboratory tests showed that the solids in the slurry settled very rapidly.

To determine the most economical means of handling and treating the slurry from the wet-scrubber system, three different processes are being investigated. In the first, the slurry is thickened in a Dorr-Oliver-type thickening tank and the thickened underflow from the thickener is then filtered. Tests will be conducted with the as-received slurry from the entrainment separator and with samples of the slurry that have been neutralized with lime. Tests will also be conducted with mixtures of slurry from the open hearth and slurry from the blast-furnace wet-scrubber systems.

In the second process being investigated, the slurry as received from the entrainment separator is centrifuged. In the third process, the solid material is settled in a simple settling tank equipped with a drag chain for removing the settled solids from the tank.

The chemical analysis of the collected dust from the open hearth is shown in Table III. The dust comprises about 92% iron oxide with only small percentages of other impurities. Means for agglomerating this dust for re-use in steelmaking operations are being investigated.

Table III—Chemical Analysis of Composite Sample of O-H Dust

Compound	Percent
Fe_2O_3	89.07
FeO	1.87
SiO_2	0.89
Al_2O_3	0.52
CaO	0.85
MnO	0.63
Alkalies	1.41
P_2O_5	0.47
S	0.40

Conclusions

In summary, the results of the test indicate that when operating at a pressure drop of 30 in. of water, a venturi scrubber will satisfactorily clean open-hearth gas to 0.05 grain per scf, and there will be little or no visible effluent in the exhaust gas other than the steam plume.

Satisfactory operation of the recycle scrubbing-water system was achieved by bleeding five per cent (25 gpm) of the total scrubbing water, containing about 1.5% solids by weight, to a settling basin.

The test program has also provided sufficient operating-cost and design information to indicate that the investment and operating costs of a venturi-scrubber system would compete very favorably with those of a precipitator-waste-heat boiler system for cleaning the gas from open-hearth shops that have an anticipated operating life of no more than a few years.

However, an economical and efficient method for cleaning the gas from those shops that have an operating life of longer than a few years is still sought. With the recent advent of siliconized glass fabric, a great deal of attention is focused on bag filtration as a promising means of cleaning the hot, corrosive open-hearth gas. Accordingly, a pilot bag-filtration unit will soon be installed to determine whether this system could be economically applied to the cleaning of open-hearth gas.

It is hoped that current research will yield solutions to the problem of open-hearth gas cleaning at a reasonable cost, so that its cleaning may soon be put in the same category as the cleaning of blast-furnace gas, a well-established practice currently being conducted on a huge scale.

AIR STUDY PROPOSED

Air Pollution in Stockholm should be investigated, the Swedish National Institute of Public Health says in support of a proposal put forward by the Stockholm city authorities. The scheme, which is motivated by the possible relationship between air pollution and such diseases as pulmonary cancer, would cover a period of three years at a cost of close to Kr. 500,000.

★ ★ ★ Section Hi-Lites ★ ★ ★

Niagara Frontier Section

A regular meeting of the Air Pollution Control Association, Niagara Frontier Section, was held at the Continental Inn Hotel, Kenmore, New York, on December 1, 7:00 PM.

George Brandt, Chairman presiding, opened with the usual self introductions and affiliations. He called attention to the presence of a distinguished guest, our old friend Arnold Arch, National Executive Secretary of the Air Pollution Control Association.

The following were nominated by Jerome Wilkenfeld, Chairman of the Nominating Committee, and second to the following officers: Chairman, Henry F. Friedrich, Buffalo Forge Company; Vice Chairman, Ernest Gedeon, City of Niagara Falls, N. Y.; Treasurer, George Amery, E. I. du Pont, Niagara Falls, N. Y.; Secretary Robert C. Boedecker, Koppers Company, Metal Products Div.; Director, Richard K. Batterson, Town of Tonawanda, N. Y.; Director, Lee I. Dickinson, Bethlehem Steel Company; Director, R. B. MacMullin, R. B. MacMullin Associates; Director, W. G. Rader, Republic Steel Corporation; Director, George F. Brandt, Mobil Oil Company; Director, Keith Eady, City of Niagara Falls, Ontario, Canada; Director R. C. Kennedy, Olin-Mathieson Chemical Corporation.

Upon motion duly made, seconded, and unanimously carried, the nominations were closed. The secretary was instructed to cast a single ballot for the slate as presented.

Henry Friedrich, Chairman Elect, made a few remarks, commenting particularly on the tremendous progress made by the Niagara Frontier Section in the past year. He accepted his election as a real challenge to continue this progress.

Officers Receive Thanks

George Brandt, Chairman, responded, thanking the officers for their support during the year and, in particular, mentioning the fine work done by Fred Harbart, Chairman of the Membership Committee, Dr. L. A. Vendetti, Chairman of Cleaner Air Week, and Henry Friedrich, Chairman of the Committee studying National-Local Relationships.

The date for the next meeting was set by Vice Chairman George Amery, Chairman of the Program Committee, as Thursday, January 26, 1961, probably at the Red Coach Inn, Niagara Falls, New York. The meeting consisted of a manufacturer's panel. The meeting was turned over to Norton Ewart of the Niagara Mohawk Power Corporation, host for the evening, who described the procedure for the plant tour.

Arnold Arch addressed the meeting briefly, pointing out that the Niagara Frontier Section is really home base for him as one of the founding members and a life member of this section. He thanked his fellow founding members for their active participation. The group included Messrs. Amery, Friedrich, Kennedy, Rader, and Warren.

Mr. Arch emphasized that the local sections are truly the lifeblood of the organization, making the APCA a year round affair. He told of his visits to other sections, and the success of new ones. Discussing the work of the National Office, he emphasized in particular, the importance of the JOURNAL. In January 1961, the JOURNAL became a monthly publication, greatly enhancing APCA's position and, of course, strengthening the publication from the standpoint of advertising revenue.

He feels the Abstracts are extremely important, and in this connection mentioned the changing complexion of the association. In 1951 there were members made up largely of smoke inspectors, power plant personnel, and railroad personnel. Now, in 1960, there are 1911 members, including a very high percentage of scientific and technical personnel. Twenty-five foreign countries are represented. The greatly broadened scope of the Abstracts is of extreme interest to this group.

Pointing out that APCA offices seek the man rather than the man seeking the office, he announced that W. L. Faith of Los Angeles would in all likelihood be the new president. He further mentioned that APCA nationally is now in the midst of an intensive and far reaching membership campaign. He paid tribute to the contribution of the Niagara Frontier in the work of expanding the membership nationally. He particularly cited the effectiveness of Roger W. Hooker of the Hooker Chemical Company in obtaining a number of industrial memberships.

In closing, he included some very interesting comments on the balanced nature of the APCA organization. The group continues to balance its membership between control officials, in-

(Continued on p. 89)

ADVISORY COMMITTEE CALLS FOR INCREASE IN RESEARCH EFFORT

An advisory committee to the Surgeon General of the Public Health Service called for a threefold increase in the nation's research effort to control the growing menace of air pollution problems.

The committee recommended that financial support of air pollution research be increased from a current estimated level of $11 million annually to about $32 million a year by 1968. The 10-man committee further recommended that the Federal Government assume 40% of this cost, industry 28% and State and local governments assume 32%.

Report Released

In a 40-page report released recently, the committee recommended these 10 national goals be set for the 1960–70 decade:

1. Determine the effects of air pollution on human health.
2. Determine the effects on the nation's agricultural economy resulting from air pollution damage to animals and crops.
3. Find better ways of measuring the economic loss from air pollution damage to materials, and soiling, and reduced visibility.
4. Find better ways of measuring and identifying air pollutants at their source and in community air.
5. Develop better techniques for assessing meteorological factors affecting air pollution.
6. Learn, through research, more about the formation of new pollutants from reactions in the air.
7. Expand our nationwide air pollution monitoring efforts.
8. Develop new methods and equipment for controlling the sources of air pollutants.
9. Build and disseminate a comprehensive body of knowledge related to the technical, legal, economic, and administrative aspects of air pollution.
10. Evaluate the legal and administrative practices related to air pollution control.

The Task Group was appointed by Surgeon General Leroy E. Burney, at the request of Secretary of Health, Education, and Welfare Arthur S. Flemming, following the National Conference on Air Pollution in November 1958. The group included educators, State and local health authorities, and industry representatives.

APCA FINANCIAL STATEMENT

Members of APCA will observe that many announcements formerly mailed as individual notices throughout the year are being carried in the JOURNAL. This is in keeping with the newly announced policy of the Board of Directors of printing these items in the JOURNAL in order to save labor and mailing costs. Accordingly, no minutes of the 53rd Annual Business Meeting will be published this year. Any reports of committees are available from headquarters upon request. The financial statement which follows is the one item of general interest to the membership which will be made available in future years immediately upon approval by the Board of Directors.

Statement of Cash, Fiscal Year May 1, 1959 through April 30, 1960

Cash on hand as of May 1, 1959		$74,133.94	
Income			
Publications	$14,594.69		
Association Activities	55,967.01		
Office Expense	353.36		
Personnel	89.05		
Other Income	2,045.54	73,049.65	
Total Cash Income			$147,183.59
Expenditures			
Publications	$21,476.98		
Association Activities	3,366.55		
Office Expense	11,236.08		
Personnel	36,456.77	$72,536.38	
Total Expenditures			$ 72,536.38
Net Cash and Security Balance as of April 30, 1960			$ 74,647.21

Other APCA Account

Fund	Balance 5-1-59	Additional Contributions	Expenditures to 4-30-60	Balance 4-30-60
APCA Abstracts	$2,216.09	$11,106.39	$5,789.08	$7,533.40

Submitted by:
MAX W. LIGHTNER, *Chairman*, Finance Committee
H. A. BELYEA
R. L. IRELAND

SECTION HI-LITES

(*Continued from p. 88*)

dustrial producers and manufacturers of control equipment. A brief discussion period followed.

The group then adjourned to the Charles R. Huntley Station of the Niagara Mohawk Power Corporation for a most interesting plant tour, with special emphasis on their provision for air pollution control. Preceding the tour, Norton Ewart briefly summarized the development of the station, noting the increase from less than 100,000 kw capacity at 250 psi in 1916 to a capacity in 1958 of 1,186,000 kw with some units at 2400 psi, making the station one of the largest in the country. He discussed, in some detail, the major air pollution control tool at the station—the high velocity stack rising some 350 ft above grade. This development of Niagara Mohawk's engineers utilizes exit velocities in excess of 5000 fpm over a broad operating range.

COURSES OFFERED IN MICROSCOPY

McCrone Research Institute announces three courses in Applied Microscopy to be offered in 1961. These courses are of three weeks' duration and provide lecture and laboratory time equivalent to four semester hours at college level. The course covers optics, photomicrography, micrometry, crystallography, fusion methods, and the application of the microscope in fields such as air pollution, forensic science, synthetic fibers, and other industrial areas.

The course will be offered in San Francisco, California, in co-operation with Arthur D. Little, Inc., from March 6 to 24, 1961. Other courses will be held in London, England, June 26 to July 7, and in Chicago, Illinois, July 10 to 28. Inquiries may be sent to D. Grabar, McCrone Research Institute, 449 East 31st Street, Chicago 16, Illinois.

LETTERS TO THE EDITOR

(*Continued from p. 52*)

thought of as the dog catcher or the boiler inspector—a matter of a man or two, a job or two, a small appropriation of variable and uncertain amount, to be abolished in a fit of economy and re-established under pressure of a vigorous minority. Even so, it is surprising how much is obtained for the effort; but the community is rarely satisfied, for the job is bigger than it was conceived to be . . ."

3 You may be interested in looking at a pamphlet in your Mellon Institute files by Herbert H. Kimball, Professor of Meteorology, U. S. Weather Bureau, published in 1913, on the subject: "The Meteorological Aspect of the Smoke Problem."

4 In the pamphlet entitled "The Facts About Pittsburgh's Soot and Dust" by Meller, published in 1931, we find this statement, "It is evident that the automobile as a source of air pollution has not received proper attention."

5 It is interesting to note that in a pamphlet published by Meller and Haythorn, April 1938, entitled "Necropsy Evidences on the Relation of Smoky Atmospheres to Pneumonia," after making an analysis of the lungs of some 3000 people, and in relation to earlier work that had been done in Pittsburgh, efforts were made to correlate pneumococcus with dirty air. Conclusions reached are quite significant and I would suggest your review of them, in particular No. 5:

"Nothing tangible was found to connect the pigment deposits with the high pneumonia incidence and high mortality rates, but the association of severe anthracosis and healing by organization formerly reported was verified."

I was particularly interested in the fact that nowhere in this paper did the word cancer appear and no reference is made to carcinogenic effects of air pollution.

6 In a paper entitled "Air Pollution from the Engineer's Standpoint," by Meller, published in January 1931, he states in his conclusion, "Control of automobile exhausts, so that the present large volume of products of incomplete combustion from this source shall be eliminated."

7 "Smoke Abatement—Where to Draw the Line" by Meller, is a paper that could be published today (written in 1939). It would only require a few word changes to become an entirely new paper.

I hope you will agree with me that the above are of interest. Whether or not they are of great enough interest to warrant publication would be up to

(*Continued on p. 91*)

Technical Council Reports

O. C. THOMPSON, Chairman, TI-2 Committee; J. S. LAGARIAS, Chairman, TA-5 Committee; A. C. PASINI, Chairman, TI-5 Committee

TI-2 Chemical Committee Report

The first report prepared by the TI-2 Committee has been approved by the Technical Council and by the Board of Directors. It was published in the April 1960 issue of the JOURNAL as an Informative Report.

This first report included a brief list of suggested questions to help control officials evaluate a chemical plant operating or to be built in his area. This approach was offered as the best method now available for dealing with the air pollution problems of the chemical industry. The foreword of this report promised supplements covering control methods and equipment for specific chemical processes.

At a meeting of the TI-2 Committee April 20, 1960, consideration was given to the choice of these supplementary reports. The minutes of this meeting include this statement:

> "As a goal, the Committee will try to have reports on six different processes ready for publication in 12 months. This means that the first drafts should be complete by November 1, 1960.
>
> "The manufacturing operations to be covered are:
>
> *1* Sulfuric Acid.
> *2* Nitric Acid.
> *3* Hydrochloric Acid.
> *4* Chlorine and Caustic.
> *5* Phosphate Fertilizer.
> *6* DDT."

Drafts of four of the six supplementary reports have been prepared and are being studied by the Committee.

At the meeting of the Committee held May 24, the following officers were elected: O. C. Thompson, Chairman; W. C. Wooding, Jr., Vice Chairman; D. C. Braun, Secretary.

The Committee has been canvassed as to present interest and availability for sharing the work load. Three were dropped from the roster at their request. Six new members have been added. The present roster totals 15.

TA-5 Dust, Fumes, Mist & Fog Collectors Committee

The TA-5' Committee on Dust, Fumes, Mist, and Fog Collectors met November 30, 1960, in New York. The following were present: E. H. R. Pegg, Aerotec; A. A. Peterson, Aerotec; G. C. Rodgers, American Air Filter; W. E. Barkowitz, American Standard; K. W. MacKenzie, American Standard; H. E. Friedrich, Buffalo Forge; H. C. Dohrmann, Buell Engineering; C. A. Gallaer, Buell Engineering; W. A. Crandall, Consolidated Edison; R. R. Leech, Ducon; R. E. Denbroeder, Koppers; J. S. Lagarias, Koppers; A. B. Walker, Research Cottrell; R. J. Jahrling, Western Precipitation.

Fine Particle Research

W. Crandall presented a summary of the ASME Power Test Code 28 progress in establishing a standard method of determining fly ash particle size distribution. The Bahco showed excellent reproducibility when properly calibrated. The ASME committee is working on establishing calibration techniques and using other less friable test dusts as well.

A final report on the particle size work at Armour is expected in the near future. Work has been completed and the report awaits duplication.

The adoption of the ASME PTC 28 work as a recommended standard for fly ash was discussed. It was agreed that this might be desirable but that the PTC 28 report and the Armour work should be reviewed first.

Sub-Committee

A need was indicated for a subcommittee whose concern would be problems unique to the wet collector field. R. Leech agreed to act as temporary chairman. The committee would establish objectives, and select a suitable name. Messrs. Friedrich and Rodgers agreed to assist Mr. Leech in the initial formulation of the subcommittee.

Determination of Dust Concentration

The status of this project was reviewed. The Technical Council of the APCA has recommended that the Board of Directors sponsor the project with technical assistance coming from the TA-5 Committee. Funds for the project would be handled by the APCA in a manner similar to the Armour work.

The need for a comprehensive literature review and state of the art search was emphasized before a specific program could be prepared. It was suggested that the problem of dust concentration determination be publicized through trade and technical journals. Contact should also be made with cognizant research organizations to determine their progress in this area.

Permission was given by nine of the 14 contributors to the particle size program to use the remaining funds to initiate a literature search on the dust concentration problem. The other companies are being contacted.

Messrs. Friedrich, Harlow, and Lagarias agreed to arrange to publicize the dust concentration determination problem.

The next meeting will be in June in New York City at the annual APCA meeting.

Need for Improved Dust Sampling

The TA-5 Committee on Dust, Fumes, Mists and Fog Collectors has been reviewing the problem of determining the concentration of dust in ducts or stacks. It has found that a need exists today for a rapid method of determining dust concentration in a stack or flue which is reliable and produces instantaneous readings rather than average readings. The present sample techniques are laborious and slow.

The increasing demands of constant and uniform control of air pollution demand better measuring techniques. Today's air pollution codes generally limit the amount of dust to the atmos-

phere on a weight or visibility reducing basis. The weight basis method is time averaging which light scattering suffers from being size selective. A universal technique is required.

A survey of organizations working on this problem here and abroad has found that many different approaches are being taken toward the solution of this problem. A satisfactory answer is still to be found, however.

The committee indicates that specific requirements which new detection equipment should have, include:

1 Determination of weight of solids accurately and with good reproducibility
2 Measurement should be instantaneous (ie, within one or two seconds).
3 Data should be recordable.
4 It is desirable that equipment should be portable and not too complicated.
5 The equipment should be relatively inexpensive.

Other desirable features would be a fairly simplified operation, suitable for high temperature operation, and correlation with light scattering data.

Advances have been made in many other branches of science, ie, Nucleonics, Electronics, Computors, etc. Many of these techniques may lend themselves to the dust concentration problem. It is hoped that focusing attention on the need for an improved dust determination method may stimulate thinking.

A number of advantages may accrue from the development of rapid dust determination. For example, if variation in performance can be determined, operation of the dust collecting equipment can be kept at a maximum level. Perhaps even more importantly, the control of the combustion operation may be correlated to the condition of stack effluent. This conceivably could apply to such widely diverse industries as in the making of steel or the grinding of wheat.

The TA-5 Committee feels that the problem of dust loading determination requires more attention. A rapid method is needed. The solution will benefit the general public, the control officials, the users of dust collection equipment and manufacturers as well.

Anyone having suggestions, comments or approaches to this problem is encouraged to contact the TA-5 Committee through the executive secretary of the APCA.

TI-5 Public Utilities Report

The Committee TI-5 Public Utilities, Thermal Electric Plants, met in New York on November 30, 1960.

1 A set of rules for organization and replacement of officers and members was adopted to insure an orderly change of personnel without loss of continuity. The Committee Chairman, A. C. Pasini, asked for an election of a new Chairman under the approval rules and E. H. Man was elected unanimously. He will assume his new duties at the next committee meeting in 1961.

2 The organization and replacement rules adopted are:

a Committee to meet at least twice a year—at the winter annual meeting of ASME and at the annual meeting of APCA.
b Committee to be composed of nine members.
c One of the members to serve as Chairman for one year.
d One of the members to serve as Secretary for two years.
e Immediate Past Chairman to serve as ex-officio member for one year.
f Members to serve for no more than three consecutive years.
g Three new members to be appointed to Committee each year by the Committee as a whole and selected at the time of ASME annual meeting.
h New Chairman to assume duties at APCA annual meeting.
i Three new members to become members of Committee at APCA annual meeting.
j Each of the three retiring members will suggest a replacement for themselves in time for consideration at the fall meeting.
k Chairman to be elected from the three members who have served on the Committee for one year.
l Secretary to be selected from the one of the three members who start the three-year term on the Committee and to serve for two years.

3 The Committee members gave progress reports on their assignments.

4 L. A. Winkelman is the new Chairman of the ASME Air Pollution Committee. In his new capacity, he becomes an advisor to the TI-5 Committee replacing G. V. Williamson.

5 The three retiring members of the TI-5 Committee will recommend replacements and the Committee will decide their replacements by letter ballot.

LETTERS TO THE EDITOR

(*Continued from p. 89*)

you. Having reviewed this material it took very little extra energy to pass the information on to you.

Very truly yours,

HARRY C. BALLMAN, *Manager*
Air Pollution Control Division
Marketing Department
National Coal Association

Welcome New Members

SUSTAINING MEMBERSHIPS

Minnesota Mining & Manufacturing Co.
St. Paul, Minnesota

COMPANY MEMBERSHIPS (LOCAL)

California Portland Cement Company
Los Angeles, California

Helms Bakeries
Los Angeles, California

Pacific Pipeline Construction Company
Montebello, California

Ralphs Grocery Company
Los Angeles, California

COMPANY MEMBERSHIPS (NATIONAL)

Continental Can Company, Inc.
Los Angeles, California

The Great Atlantic & Pacific Tea Co.
Los Angeles, California

Southwestern Portland Cement Co.
Los Angeles, California

INDIVIDUAL MEMBERSHIPS

Andresen, William V.
New York, New York

Bender, Donald C.
Jackson, Michigan

Carney, Robert L.
Wheeling, West Virginia

Doering, Robert D.
Whittier, California

Geddes, Bruce W.
Ottawa, Ontario, Canada

Glenn, Richard A.
Pittsburgh, Pennsylvania

Hill, William H.
Pittsburgh, Pennsylvania

Hinds, Gene W.
Newark, New Jersey

Marshall, J. R.
New York, New York

McEnaney, Joseph P.
Boston, Massachusetts

Megarity, A. L.
Houston, Texas

Morrill, Jr., E. Elbridge
Cincinnati, Ohio

Muller, J. Henry
Weehawken, New Jersey

Patton, Ralph K.
Buffalo, New York

Schaller, G. Mahlon
St. Paul, Minnesota

Squires, Arthur M.
New York, New York

Strassburger, Julius H.
Weirton, West Virginia

Thomas, Dean G.
Stoughton, Wisconsin

Vance, E. R.
Canton, Ohio

Help Boost APCA Membership

(*See page 59*)

GENERAL JOHN HULL CHARGES AICE WITH DUTY OF POLLUTION ABATEMENT

"Industry in general and the chemical industry in particular not only are aware of, but are taking action to solve, serious problems arising from our complex society in the area of environmental health," said General John E. Hull, president of the Manufacturing Chemists' Association.

In an address before the 53rd Annual Meeting of the American Institute of Chemical Engineers, General Hull emphasized the intense degree of responsibility of the chemical industry in air and water pollution abatement, industrial medicine and safety, hazardous substances labeling and assuring the nation of an adequate and safe food supply.

The hundreds of industry experts who devote a considerable amount of their time to finding solutions to these problems which are a by-product of our increasingly technological society are evidence of the responsibility felt by industry, he said.

In citing just one area, that of water pollution abatement, General Hull pointed to a "set of principles" now being arrived at by such experts working in the MCA Water Pollution Abatement Committee.

Among them were:

"Proper control of stream pollution is one of the obligations of responsible corporate citizenship.

"Avoiding harmful pollution is a necessary business cost. As with other aspects of business, qualified people with clearly defined responsibilities must be assigned to bring and keep pollution under control.

"The chemical industry recognizes the community nature of water pollution control and desires to co-operate fully with the control agencies that are responsible for safeguarding the health and welfare of the people.

Solution Should Be Shared

"The solution of stream pollution problems of the individual companies is not a determining factor in competitive production and therefore the knowledge pertaining to solution of these problems should be freely shared."

Throughout the chemical industry, General Hull stated, there is carried out "a positive program for the specific purpose of recognizing hazards to health and safety." This program involves the planned study of harmful properties and the appropriate consideration of these properties in the development and in the manufacture of new products and new uses.

"We study toxic properties in animals for application to man. We determine harmful properties for aquatic life and for waste treatment systems. We examine flammability and other chemical properties from the viewpoint of hazards."

Despite all these advances, the MCA President said, "unfortunately there are matters about which we are far less confident, a current and outstanding example being the testing for carcinogenic properties. The total effort expended in this testing is substantial and quite expensive. As time goes on we can expect improvement in methods and understanding, but we will always have technical questions."

The head of the national chemical organization stressed the fact that rather than being individual problems for individual segments of our society, "all problems in this field, as in most others, become problems of (the entire) society."

An example can be found in the area of certain synthetic detergents. "These are products which the housewife would not wish to give up. However, they have had a technological impact on the sewage problems in many areas and on the water supply of many communities. As problems have become apparent, hundreds of thousands of dollars of research work has been accomplished by industry. If and when it is decided that these otherwise beneficial products are creating too great a hazard in the streams, then certainly society—of which we all are a part—may feel the consequences in terms of a poorer or different performance by some other product, possibly at an increased cost.

"Another way of expressing this point is that more and more solutions to the problems of environmental health will be found at the level of society. This is where I think the answer lies."

WILLIAM T. INGRAM
Consulting Engineer
Sanitary and Public Health Engineering—Planning Design—Research—Water—Sewage—Refuse—Industrial Wastes—Air Pollution Control—Industrial Health
Offices:
East Coast
20 Point Crescent
Whitestone 57, N.Y.
West Coast
90 Panoramic Way
Walnut Creek, Calif.

Los Angeles County Orders Car Devices For Fume Control

Los Angeles County supervisors recently ordered fume-control devices installed on 3500 county cars within the next six months.

And the California Motor Vehicle Pollution Control Board appropriated $53,000 for testing several models of automobile exhaust purifiers. The laboratory testing will be done by Los Angeles County Air Pollution Control District officials, who have had the most experience in the field.

Both measures were aimed, theoretically, at installation of exhaust control devices on all new cars sold in California in 1962, and on all cars in the state by 1965. But smog control time-tables are flexible. Only a year ago officials had hoped 100% purifiers could be put on 1961 cars.

Most students of the problem contend that the 3,200,000 automobiles in the county are now the main source of Los Angeles' smog. Controls have been placed on smog-producing industries and home trash burning has been eliminated generally throughout the county.

Supervisor Warren M. Dorn said studies showed an average of two gallons of gasoline was burned daily by each of California's 8,000,000 motor vehicles. This amounts to 16,000,000 gallons daily in the state, 6,400,000 gallons in Los Angeles County.

Special Pipe to Be Used

County cars will be equipped with a pipe that will lead crankcase gases into the carburetor intake channel. The gases are burned in the cylinders instead of escaping into the air. Up to 80% of the gases is consumed and about 20% of hydrocarbons removed, it was said.

The cost of the device and installation was placed at $15.

Similar devices have been put on new cars sold this year in the county under an agreement with the automobile industry.

Most manufacturers said a 100% purifier would cost $50 to $100.

The supervisors would like to see the state-wide time-table stepped up to require devices on all new cars in California next year, and all other cars in the state in 1963.

The state board was established by legislative action last April. It works with the state Board of Public Health. Probably six or seven devices will be given extensive tests through July to narrow down to the best.

J & L TO INSTALL NEW EQUIPMENT IN AIR POLLUTION CONTROL PROGRAM

Magnetic control and analog information systems designed by Hagan Chemicals and Controls, Inc., are the keystones of a new open hearth air pollution control installation at the Pittsburgh Works of Jones and Laughlin Steel Corporation.

J & L, co-operating with Allegheny County's air pollution control program, is installing electrostatic precipitators manufactured by Koppers Company, Inc., on 11 open hearth furnaces. Hagan PowrMag magnetic controls and a Hagan AIM (Alarm Indicating Monitor) will play important roles in the over-all automation of the eight precipitators and the 11 waste heat boilers that cool furnace gases ahead of the precipitators.

Early planning for the job envisioned a control panel at each boiler and precipitator. However, when operating and supervisory requirements were spelled out, the thinking quickly evolved toward complete "centralization" of control. Thus, the PowrMag solid-state control systems will reach out from a single 40-ft control house to control equipment spread out over an open hearth shop more than ¼-mile long.

The Hagan AIM (the steel industry's first, for this purpose) will provide alarm and indication if any of 220 critical flows, temperatures, pressures or levels get out-of-limits. Thus, the operator in the central control house has continuous, automatic supervision of the entire system.

Panel to Show Info

A graphic control panel will present clear operating information at all times, and further centralize the operation of the co-ordinated systems.

J & L will obtain these benefits from the system; benefits that were taken into account when justifying the initial investment:

1 Effective control of troublesome open hearth dust.
2 Bonus steam from the waste heat boilers.
3 Most important of all, intelligent automation of the process to minimize operating costs.

Steam will be produced in the waste heat boilers at a temperature and pressure that will permit its utilization in the Power House and Blast Furnace Blower House located on the other side of the Monongahela River from the Open Hearth Shop. Lower pressure steam, presently available for fuel atomization in the open hearth furnaces, will drive the waste heat boiler feed pumps and induced draft fans.

The PowrMag systems will control boiler drum levels, flue gas system draft, precipitator paralleling, feedwater pressure, and feedpump recirculation.

One waste heat boiler and precipitator combination was installed and put into operation on No. 41 furnace in 1959 to gain experience. Operation of this facility revealed a number of refinements which are incorporated in the complete layout.

The new waste heat boiler and precipitator control is tied into the existing furnace control and electrically interlocked to provide safety of operation. Since the 11 waste heat boilers are all under the supervision of one watch engineer, provision is made to direct hot flue gases from the open hearth over to existing natural draft stacks in the event of operating difficulties. This will prevent interference with steel production while the operating difficulties are being located.

Provision is also made for sequential restoration of the boilers after outages. Gradual warm-up of the boiler and final transfer of draft control from the stack to the waste heat boiler and precipitators is accomplished in steps.

Plenum Collects Gases

A large plenum, or header, collects the gases from the open hearth furnaces and discharges into the eight precipitators. Pressure in this plenum is controlled at a constant value by varying the rate of flow to the eight precipitators. The signal from the plenum pressure controller goes to eight collector flow controllers, acting as a common set point for all eight. These eight flow controllers in turn operate dampers on the discharge of each precipitator. This parallels the flow equally between all eight or any other operating number of precipitators.

The "centralized control" concept, practically applied on this job, is another example of the operation of all the control and measurement apparatus on a process from a central location. The growing acceptance of industrial centralized control stems from a number of considerations, including: ease of control from a central location; greater control accuracy from centrally available measurements; reduction of supervisory requirements; increased safety with all measurement and control indications at the fingertips; and faster plant-wide operation by a single operator.

Personalia

The Board of Directors of Airkem, Inc., has announced that **John A. Monkman** was elected Chairman of the Board and Chief Executive Officer and **Frank W. Conkling** was elected President of Airkem, Inc., as announced by the Board of Directors. These positions were previously held by William H. Wheeler, founder of the Company, who passed away on July 2, 1960.

Mr. Monkman has been Vice-President and Treasurer of the Company since 1947. He will continue to hold the office of Treasurer. An accountant by profession, Mr. Monkman was retained by Airkem as a financial consultant in 1943, soon after the firm's founding. He was elected to the Company's Board of Directors and became its comptroller that same year. Mr. Monkman is a member of the American Institute of Accountants, the New York State Society of Certified Public Accountants, and the Board of Governors of the Canadian Club. He was born in Williamsport, Pennsylvania, in 1901.

J. A. Monkman

Mr. Conkling joined Airkem as a field salesman after his discharge from the U. S. Army at the end of World War II. In 1948 he started the Smoke Odor Service and Decontamination Service and became the manager. Elected to the Board of Directors in 1953, Mr. Conkling has served as Manager of New Product Development, Director of Research, and Director of Distributor Sales. Since 1955 he has been Vice-President in Charge of Sales in the Western Hemisphere. Mr. Conkling holds a B.S. Degree in chemistry from the University of Chattanooga and did graduate work in engineering at the University of Vermont.

F. W. Conkling

* * *

Pierce Hollingsworth has been appointed manager of the Industrial Gas Cleaning Department, Metal Products Division, Koppers Company, Inc.,

(*Continued on p. 94*)

Personalia

(*Continued from p. 93*)

Baltimore, Maryland, it was announced recently. He had been chief engineer of the Division's Coupling Department since 1956.

Mr. Hollingsworth graduated from the University of Delaware in 1943 with a degree in mechanical engineering. He then joined the U. S. Army and served with the Ordnance Department until 1946. In 1946 and 1947 he was associated with the Packard Motor Car Company at their Aircraft Engine Development Laboratory, Toledo, Ohio.

From 1947 to 1950 Mr. Hollingsworth was a project engineer with the General Engineering and Research Corporation in Trenton, New Jersey. In 1950 he became chief design engineer with Fisher and Porter, Hatboro, Pennsylvania, and held this position until he joined Koppers in 1956.

* * *

The **Buffalo Regional Sales Office** for the Scientific and Process Instruments Division of Beckman Instruments, Inc., has been moved to a new location at 2451 Wehrle Drive, Buffalo 21, New York.

The office formerly was located at 3053 Main Street in the same city.

Joseph P. Addonizio, Manager of Beckman's Eastern Region, says the move to larger quarters was necessitated by expanding operations of the Buffalo office.

The office is staffed by Charles D. Kennedy, sales engineer for laboratory instruments; Joseph Hauber, sales engineer for process instruments; and Frank H. Goodwin, service engineer.

* * *

The Scientific and Process Instruments Division of Beckman Instruments, Inc., has opened a Boston Sales Office in Cambridge. The address of the new office is: Beckman Instruments, Inc., 12 Norfolk Street, Cambridge 39, Massachusetts.

The Boston Sales Office in Cambridge is staffed by Robert Sankey, Sales Engineer for the firm's scientific analytical instruments, and Robert Stillman.

* * *

Carl R. Flodin, Consultant, announces the opening of his office for air pollution control engineering in the process industries. He is located at 2744 Monterey Road in San Marino, California.

* * *

R. J. Dorey of Wayland, Massachusetts, has been appointed sales representative for The Research Appliance Company in their complete line of laboratory testing equipment and air and smoke samplers.

NEWS FROM THE CONTROL DISTRICTS

City of Columbus

The past month, the division has received requests from four Ohio cities and one West Virginia city for information on our Air Pollution Code in Columbus. This again proves that people are becoming more conscious of what is going into the air every day.

One of the weather balloons that was released on October 28, in connection with "Cleaner Air Week," was found November 16 in Meridithville, Virginia, a distance of some 310 miles from Columbus.

At the request of an attorney representing residents in the Champion Avenue area in their claim of plant damage, a meeting was held in the Health and Safety Building, with the residents, their attorney, chief smoke regulation engineer, and the officials of the chemical company. It was decided, that the attorney would contact the chemical plant's insurance company to see what could be worked out. The division agreed to continue running air sampling tests in the area.

Bay Area—Air Pollution Control District

A statement issued recently by Chairman Andrew C. Byrd established the Bay Area Air Pollution Control District's opposition to and disagreement with the granting of permission to demolish the buildings at Marin City, California, by burning.

"We were informed on December 8, 1960, by the chief of the Marin County Fire Department that such permission would be granted. Our air pollution control officer informed the fire chief that the district was opposed to such activity and that other methods of disposal could have been used.

"However, our District regulations and laws state that granting permission to carry on an open burning because of fire hazard is within the jurisdiction of the chief of the fire department in which such an action is to take place. The burning of the buildings at Marin City is not illegal but rather does not conform to good air pollution control practices." stated Mr. Byrd.

"The Air Pollution Control District has established procedures for the consideration of variances to its regulations. Had these procedures been used and the variances granted by the Hearing Board, then the burning which is now going on at Marin City would have been accomplished under a controlled plan. This plan would have taken into consideration the meteorological conditions, making sure that the fallout of ashes and soot would not have affected the surrounding area and that the smoke would have been completely controlled."

Mr. Byrd went on to say, "We sincerely hope that other fire department chiefs will give more consideration to existing air pollution control regulations and the variance procedures available, before permitting such an operation to take place within their jurisdiction."

According to the Technical Division of the Bay Area Air Pollution Control District the burning of the buildings at Marin City will contribute several tons daily of air pollution which could have been controlled by demolition of the buildings and hauling away to dumping areas.

The Bay Area Air Pollution Control District has also protested the issuing of a permit to burn building demolition debris which was put forth by the Fremont Fire Department in the East Bay Area.

The Board of Directors of the Bay Area Air Pollution Control District postponed action until the January 4, 1961, meeting on whether to ask the State Legislature for an additional one cent tax levy to enforce the District's anti-smog regulations.

The Board's Budget and Finance Committee unanimously recommended that the Board ask the Legislature to raise the District's one cent taxing power an additional cent. Committee Members who voted in favor of the recommendation were San Mateo County Supervisor T. Louis Chess, Chairman; Berkeley Councilman Weldon L. Richards and Contra Costa County Supervisor Warren G. Buchanan.

Following a lengthy discussion the full Board felt the need for additional time to consider the tax increase. Decision was made to put off any further discussion of the matter until the next meeting.

In line with the recommendations made in a study conducted by the six County Administrators of the District, the Board unanimously approved the Personnel and Executive Committees recommendation that the District contract with the State Co-operative Personnel Services for a job classification and salary survey and the development of grievance procedures, the total cost not to exceed $1050. Other County Administrators' recommendations were complied with and approximately $8000

(*Continued on p. 95*)

CONTROL DISTRICTS

(*Continued from p. 94*)

was made available to the District for the securing of additional cars for the Enforcement Division, clerical help in various departments, and other funds available and needed to meet the immediate needs of the District.

Advisory Council Chairman William B. McCormick reported that the Board would receive the Council's recommendations on the improvement and control of watersheds and on orchard heaters at the January meeting.

Control Officer Benjamin Linsky informed the Board that the District has received 150 forms from Bay Area industries that cannot complete their corrections by January 1, 1961, which specify their plans for compliance with Regulation 2. Linsky stated that many were fully acceptable, while others are still being studied by the District staff.

Philadelphia

Permit approval was given for the following control installations: one paint spray booth with a total capacity of 10,000 cfm; one incinerator with a total capacity of 200 lb per hour; a special incinerator to burn off residue from drums used to ship combustible liquids at a plant which has been a longstanding problem due to their former practice of open burning these drums; a venturi wet scrubber with a capacity of 3000 cfm used to treat the effluent from an aluminum smelting furnace during chlorination procedure. The aerosol removed will consist mostly of aluminum chloride and some traces of irritating chlorine gas which has created past air pollution nuisances.

The following are examples of the activities of the investigations unit:

Major efforts were directed toward the enforcement of the regulations on open dump burning following the order from the Managing Director's Office for the Fire Department to put out all of these fires. To effectively co-ordinate this activity, the Air Pollution Control Inspectors have been ordered to make three shift checks of all open dump areas daily; the health districts have been notified to have sanitarians inspecting dump areas report all fires; appropriate persons in municipal and fire radio room have been contacted to assure that interagencies communications keep information on fires up to date; and contact has been made with persons in Streets Department and Redevelopment Authority to keep them informed of fires on their ground. Where necessary, these agencies have had barriers erected and have had police checks made to combat the

(*Continued on p. 96*)

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CONTROL DISTRICTS

(*Continued from p. 95*)

problem of illegal dumping and resulting fires.

An unusual odor problem occurring in a telephone sales office located in a diversified manufacturing building was tracked down by an Air Pollution Control Inspector. The source of this odor was a plating tank venting acetic acid mists to a vent below the window of the complainant's office. A control system to collect the acid mists was suggested. The engineering aspects of the proposed system were studied by the investigations unit supervisor who visited the site, made contact with the equipment manufacturer, and made arrangements for the installation permit.

On investigating a localized chemical odor, the Air Pollution Control Inspector and the Laboratory Unit Supervisor tracked down and identified the odor as trimethylamine. A meeting held with the company involved resulted in having our project engineer thoroughly study the plant processes for the exact sources of this odor. It was found that there were at least seven points where odors were prevalent. Recommendations were made to provide control for these emissions.

New York

On October 31, Arthur J. Benline, Commissioner of the Department of Air Pollution Control, announced that violation notices served during the first nine months of this year established a record for the period. At the same time, summonses issued were second only to 1958, while citizen complaints declined almost 1300 below the record set in 1959.

The enforcement figures of the Department for January through September 1960 were as follows: summonses issued, 443; violation notices issued, 3757; fines levied in Municipal Term Court, $12,480; office hearings held with violators, 78; smoke alarms ordered, 425; complaints received, 12,167. The figures for January through September 1959 were as follows: summonses, 400; violation notices, 3566; fines, $10,230; office hearings, 154; smoke alarms ordered, 528; complaints, 13,456.

Commenting on the figures, Commissioner Benline said: "The complaints we are receiving from the public are more accurate, thanks to the co-operation we have received from newspapers, radio and television. As a result, fewer but more specific complaints are resulting in more violations being found by our Inspectors. A recent drive to clear up violations has resulted in summonses reaching a figure second only to the record year of 1958."

THREE ARF MEMBERS GET ELECTED TO POSTS AT MAPPA MEETING

Three Armour Research Foundation staff members were elected to top posts in the Midwest Air Pollution Prevention Association, Inc., at the group's annual meeting December 13 at the Hotel Sherman.

New president of MAPPA is Daniel A. Sullivan, ARF consultant. Lewis Evans, Chicago and Indiana Railroad Co., was re-elected first vice-president. Second vice-president for the coming year is Dr. George S. Gordon, ARF director of chemistry research.

Douglas R. Fuller, Northern Trust Co., was re-elected treasurer of MAPPA; and Dusan Ljubenko, administrative supervisor, ARF chemistry research division, was elected secretary.

During the meeting, members heard an annual report of activities of MAPPA by Dr. Haldon A. Leedy.

CLASSIFIED

PRODUCT MANAGER, AIR POLLUTION CONTROL EQUIPMENT—Division of major corporation engaged in the manufacture of dust collectors has a "ground floor" position available for an executive experienced in the development and marketing of air pollution control equipment.

Candidate should be graduate engineer with a minimum of 10 years of experience in field of both mechanical and electrostatic collectors. Broad experience, including design, application, and sales of the various types of dust collectors, desirable, as is familiarity with various air pollution control markets.

Interested candidates should forward complete resumes, including salary requirements in complete confidence, to: Box G, % Journal of the Air Pollution Control Association. (Our employees know of this ad.)

Use of Instrumentation

(*Continued from page 82*)

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DISPERSION STUDY OF STACK GASES

(*Continued from page 65*)

the study are Dr. T. F. Hall and C. M. Davidson, A. E. Owen, H. L. Elmore, Harold Stott, E. D. Myers, and W. O. Bianconi. Illustrations were prepared by A. E. Owen.

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TRAINING COURSE SPONSORED BY PHS

A special one-week training course, "Medical and Biological Aspects of Air Pollution," was presented for the first time December 12 to 16 at the U. S. Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati. The training course, sponsored by the Public Health Service Division of Air Pollution, was conducted by the Air Pollution Unit of the Center's Training Program.

The course consisted of a review of medical and biological knowledge related to air pollution and of current research activities in this field. Lecturers for the course were drawn from the research programs of the Public Health Service Divisions of Air Pollution and Occupational Health, from research foundations and from schools of medicine and public health. Registration for "Medical and Biological Aspects of Air Pollution" was open to the medical, public health, and engineering professions.

Speakers included Harry P. Kramer, Chief of the Sanitary Engineering Center Training Program; V. A. MacKenzie, Chief of the Public Health Service Division of Air Pollution; and Dr. Richard A. Prindle, Deputy Chief.

CONFERENCE HELD ON AUTO EXHAUST

On December 5 and 6 the Fourth Conference on Methods in Air Pollution Studies, devoted entirely to auto exhaust problems, was held in Los Angeles. More than 100 engineers and chemists from private industries, air pollution control districts, universities and research institutes attended the two-day session sponsored by the California State Department of Public Health. Highlights of the Conference were a tour of the automotive test facilities at the Los Angeles Air Pollution Control District, an address by Donald Jensen, the newly appointed executive officer of the Motor Vehicle Pollution Control Board, and a paper by Dr. Steven Nicksic of the California Research Corporation describing a new technique for measuring the olefinic content of auto exhaust.

Other participants presented papers concerned with the importance of auto exhaust constituents in the formation of air pollutants. The conference emphasized the need for evaluating existing analytical methods.

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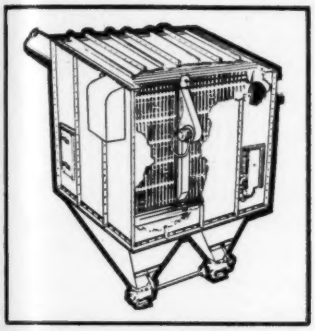

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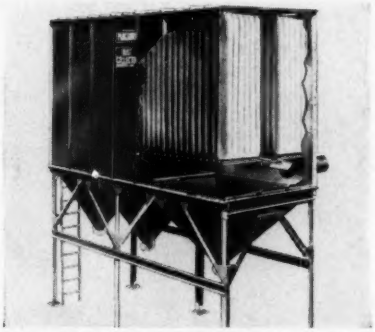

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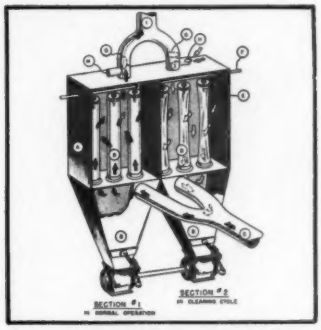
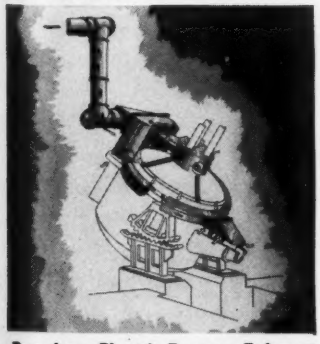
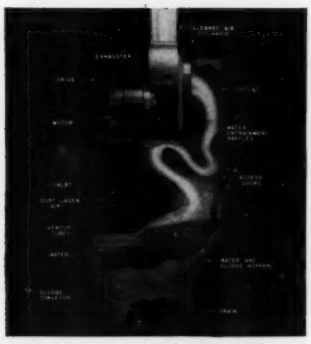


For elevated temperature fume and dust problems, the Pangborn Cloth Tube Collector featuring Pressure-Jet fabric cleaning developed specially for glass fibre fabrics.



Pangborn Electric Furnace Exhaust Hood . . . captures dust, fumes, smoke at electric melting furnaces with minimum interference to operations or maintenance. This hood is applicable to furnaces of all types and sizes.



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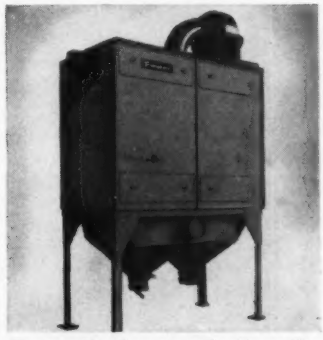

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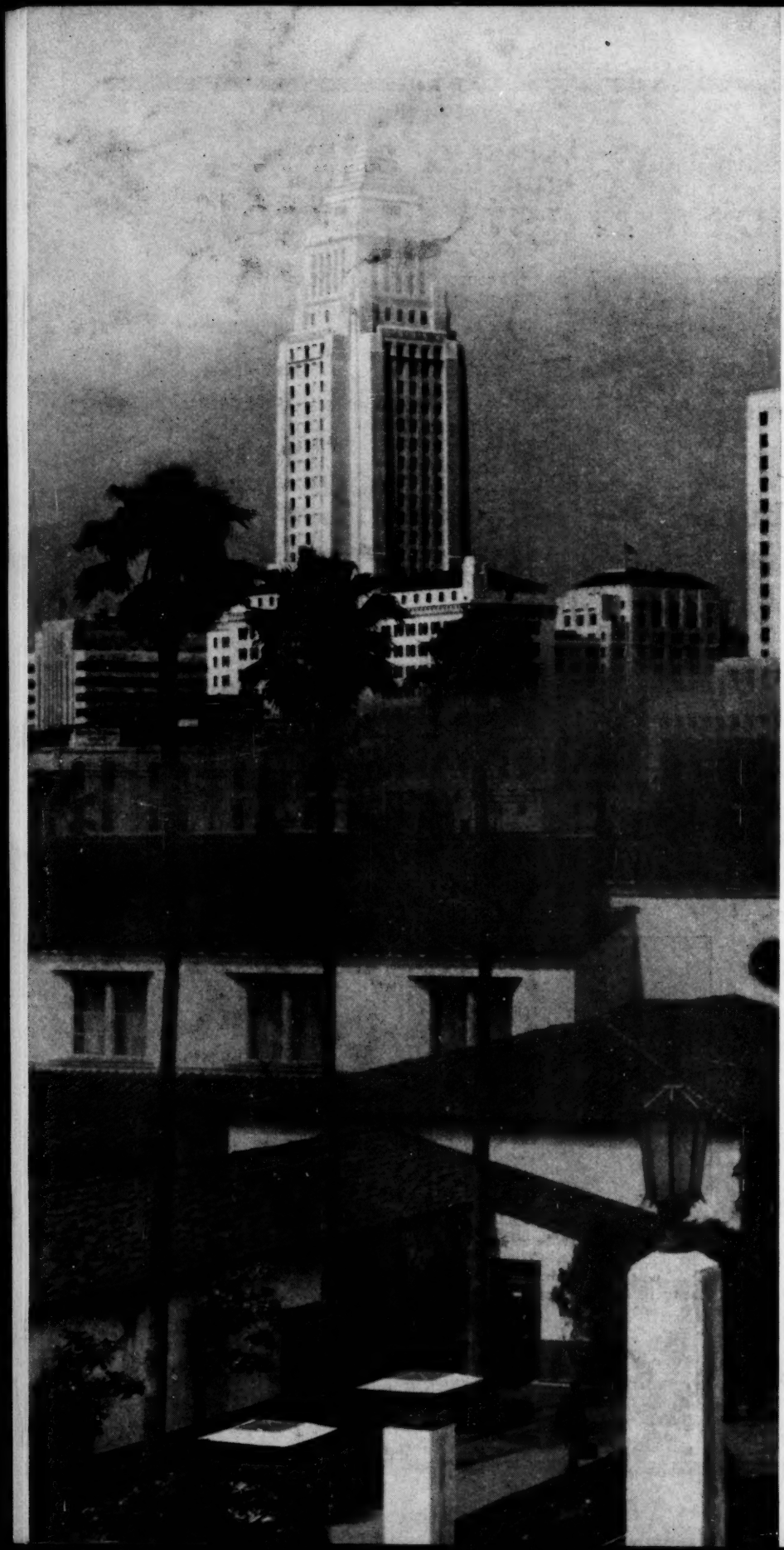

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